The trilobite fauna of the Raheen Formation (upper Caradoc), Co. Waterford, Ireland

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Synopsis

The Raheen Formation contains a diverse trilobite fauna dominated by *Tretaspis ceryx* Lamont and *Ampyx austinii* Portlock, which are redescribed along with *Homalopteon portlockii* (Salter) and *Salteria involuta* Salter. Ten other species are described, including *Sphaerocoryphe murphyi* sp. nov. and possible new species of *Mesotaphraspis* and *Flexicalymene*. A lectotype of *Homalopteon portlockii* (Salter) is selected, and a neotype designated for *Ampyx austinii* Portlock. The fauna is thought to represent a fairly deep water assemblage of late Caradoc age.

Introduction

The Ordovician sedimentary and volcanic rocks north of Newtown Head, Co. Waterford (S 700070, Fig. 1) were first discussed in detail by Reed (1899: 721–725), although elements of the fauna had previously been described by Portlock (1843), M'Coy (1846), Salter (1849, 1864) and Davidson (1866). Reed (1899: fig. 1) introduced the term 'Raheen Shales' for the fossiliferous sandy mudstones and provided a faunal list based on his own and earlier collections.

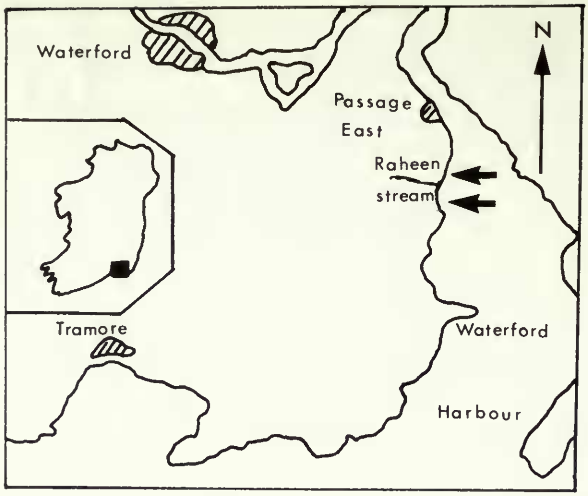


Fig. 1 Map showing localities (arrowed) of Raheen Formation exposures along west bank of Waterford Harbour.

Since then, the unit has received little published attention although Mr G. J. Murphy studied the formation in the 1950s in conjunction with his work on the older Tramore Limestone. The Ordovician stratigraphy of Co. Waterford has been formalized in recent years (Mitchell *et al.* 1972, Williams *in* Williams *et al.* 1972, Carlisle 1979), with the sequence at Newtown Head largely being ascribed to the Raheen Group of which the Raheen Shale Formation forms a part. A simplified section through the formation was given by Paul (1984: fig. 42).

Several trilobite species have been described originally from the Raheen Formation (Portlock 1843, Salter 1849, 1864, Lamont 1941). One of these, *Homalopteon portlockii* (Salter), is the type species of its genus. The present study involves the redescription of these as well as the other trilobites, a quantitative assessment of the trilobite fauna and a consideration of the age of the formation.

Sampling

The foreshore sequences north and south of the Raheen Stream were examined and sampled by Tripp and Morris in 1981 and 1982. The succession north of the stream is heavily tectonized and probably includes older strata (possibly the late Llandeilo–early Caradoc Tramore Limestone) which are poorly fossiliferous but yielded specimens of *Ampyxina*, a taxon not represented in the Raheen Formation. The strata above these beds on the north side of the stream include a typical Raheen fauna and are included in the descriptions herein (Sample N, Table 2, p. 94). The more complete sequence south of the stream dips steeply to the north-west and limited sedimentary evidence suggests it may be inverted. The section was measured and ten large samples made (see p. 93). Blocks containing fossils were collected and in many cases were broken up further in the laboratory, prior to and during examination under the binocular microscope. The new type and figured specimens along with a representative sample of each species are now housed in the Department of Palaeontology, British Museum (Natural History), London (numbers prefixed It); the remainder have been donated to the National Museum of Ireland, Dublin. The majority of the trilobites recovered (551 out of 719) were from Sample 3, which comprises two collections of approximately equal numbers made on each of the two sampling seasons. They proved to be virtually identical in percentage composition, indicating the thoroughness of the sampling. The sample horizons and general lithologies are shown in Table 1.

Table 1 Sample horizons and general lithologies of sequence south of Raheen stream, Co. Waterford. Note that many of the beds are ashy, and the overall abundance of ash increases up the succession.

Sample	Thickness	Lithology
[TOP]		thick felsite intrusion
10	2·3 m	olive brown shales
	[1·5 m	no exposure]
9	2·9 m	olive green/brownish shales with nodules
8	2·8 m	massive dark ashy mudstones
7	5·5 m	olive green/brownish shales with nodules
6	4·0 m	soft shales
5	1·1 m	olive green/brownish shales with nodules, extensively faulted thin (1 cm) chert band
4	6·1 m	grey/green mudstones
3	1·8 m	dark grey/green mudstones with nodules
	2·9 m	felsite intrusion
2	1·8 m	dark grey rusty-weathering shales
	1·0 m	felsite intrusion
1	2·8 m	light grey rusty-weathering shales
[BASE]		
	Total 36·5 m	

Fauna

The fauna of the Raheen Formation is dominated by trilobites and brachiopods, but rarer elements include echinoderms (see Paul 1984), bryozoans, gastropods, machaeridians, ostracods and graptolites. The brachiopod fauna is being assessed by Dr D. A. T. Harper of University College, Galway but the dominance of *Onniella* noted by Reed (1899: 723, as '*Orthis argentea*') is confirmed (personal communication D. A. T. Harper, August 1984). The composition of the trilobite fauna is summarized in Table 2, which shows the absolute numbers of sclerites of each species, the number of specimens of each species in the samples which contained trilobites and the percentage of specimens of each species in the Raheen Formation as a whole. Old collections from the unit housed in the National Museum of Ireland (NMI), British Museum (Natural History) (BM(NH)), Geological Survey Museum (BGS GSM), Sedgwick Museum, Cambridge (SM), Birmingham University Museum (BU), Royal Scottish Museum (RSM), Trinity College, Dublin (TCD) and personal collections of Mr G. J. Murphy (now NMI) have been examined in the course of the present study but are not included in the percentage values in Table 2. Two species, both known from single specimens, *Salteria involuta* Salter and *Yumenaspis* sp., are known only from these older collections and are included in the table for the sake of completeness.

The trilobite fauna is dominated by *Tretaspis ceryx* Lamont and *Ampyx austinii* Portlock, which constitute 51·0 and 26·6% respectively of the trilobite remains in our collections. No other species exceeds 4·0% of the sample and six of the 16 each comprise less than 1%. This dominance of a trinucleid and a raphiophorid is also seen in the broadly coeval Høgberg Member of the Solvang Formation in Ringerike, Norway (Owen 1979: 250, fig. 6) and the slightly older Nakholmen Formation in Oslo-Bærum, Norway (Harper, Owen & Williams 1985). The Høgberg Member is a pure limestone and the Nakholmen Formation a black shale with dark limestone nodules and thus there is no simple relationship between litho- and biofacies. The Nakholmen Formation trilobites occur in association with an *Onniella*-dominated brachiopod fauna at the top of the formation which marks a transition from fairly deep water, possibly periodically euxinic facies, to the more ventilated conditions of the overlying Solvang Formation. Whether the trinucleid–raphiophorid association reflects a particular

Table 2 List of trilobite species, the abundance of their skeletal elements and their distribution in samples of the Raheen Formation. The single specimens of *Salteria involuta* and *Yumenaspis* sp., known only from older collections, are also listed here. The number of cephala, cranidia and lower lamellae (= free cheeks) of *Tretaspis* is given as a single feature (*). Cephala of all taxa are very rare compared with cranidia. The specimen of *Miraspis* sp. listed as complete lacks a pygidium. The total for *Homalopteon portlockii* includes four fragments of unknown position in the exoskeleton. Two indeterminate odontopleurid fragments have been omitted from the table. Sample N is from north of the Raheen Stream above the probably older strata there (see p. 92); the remaining samples are from south of the stream and their positions in the measured section are given in Table 1. Samples 2, 6, 9 and 10 did not yield any trilobite remains. (ceph.—cephala. cranid.—cranidia. fr.ch.—free cheeks. hyp.—hypostomata. thor.—thoraces. pyg.—pygidia. comp.—complete).

Species	Skeletal parts								Samples							
	ceph./cranid.	fr.ch.	hyp.	thor.	pyg.	comp.	Total	%	1	3	4	5	7	8	N	Figs
Remopleurides sp.	–	–	1	–	–	–	1	0·1	–	1	–	–	–	–	–	15
Homalopteon portlockii (Salter)	8	–	1	9	5	–	27	3.8	2	13	1	6	4	–	1	2–8
Illaenus sp.	3	1	–	1	–	–	5	0·7	–	4	–	–	–	1	–	12
Decoroproetus sp.	2	–	–	–	1	–	3	0·4	–	3	–	–	–	–	–	13–14
Harpidella (s.l.) sp.	10	3	–	–	–	–	13	1·8	–	13	–	–	–	–	–	9
Mesotaphraspis sp. nov.	1	–	–	–	–	–	1	0·1	–	1	–	–	–	–	–	16
harpid, gen. et sp. indet.	9	–	–	–	–	–	9	1·3	–	8	–	–	–	–	1	10–11
Tretaspis ceryx Lamont	328*		–	9	24	5	366	51·0	–	300	3	7	19	13	24	29–40
Ampyx austinii Portlock	54	11	2	31	88	5	191	26·6	–	118	20	28	19	4	2	17–25
Salteria involuta Salter	1	–	–	–	–	–			–	–	–	–	–	–	–	27–28
Yumenaspis sp.	1	–	–	–	–	–			–	–	–	–	–	–	–	26
Sphaerocoryphe murphyi sp. nov.	2	–	1	–	3	–	6	0·8	–	6	–	–	–	–	–	42–47
Cybelinae indet., cf. '*Cybele*' *mchenryi* Reed	7	5	2	5	5	–	24	3·3	–	22	–	–	–	–	2	49–56
Flexicalymene sp. ?nov.	16	1	–	1	10	1	29	4·0	–	25	–	1	–	–	3	59–70
Calyptaulax sp.	3	–	–	1	2	–	6	0·8	–	6	–	–	–	–	–	57–58
Platylichas laxatus (M'Coy)	4	–	2	1	4	–	11	1·5	–	9	–	2	–	–	–	71–78
Primaspis aff. *caractaci* (Salter)	14	4	–	–	2	–	20	2·8	–	18	–	–	–	–	2	79–84
Miraspis sp.	4	–	–	–	–	1	5	0·7	–	4	–	–	–	–	1	85–88
						Grand total	719									

depth or substrate consistency (? soft substrates) remains debatable. Brenchley & Cocks (1982) defined two contiguous shelly associations in the upper Rawtheyan of Oslo-Asker as the *Onniella* and *Tretaspis* Associations, with the former occupying a position higher on the palaeoslope (mid-shelf) than the latter (deep shelf). Both associations are very much sparser than the Raheen fauna, and although *Tretaspis* is the dominant trilobite in the *Tretaspis* Association, and in some samples of the *Onniella* Association, raphiophorids are rare. Thus close comparisons are not possible. Excluding the trinucleid–raphiophorid dominance, the overall generic/familial composition of the Raheen fauna, including rare elements such as *Yumenaspis* and the *Salteria*, bears some similarity to associations in the lower Caradoc Balclatchie Group at Dalfask, Balclatchie and Penwhapple Burn near Girvan, south-west Scotland (Tripp 1980: table 1). These were interpreted by Tripp (1980: 135) as representing deep water environments. Similarly *Yumenaspis* in its type occurrence in the Ch'i-lien Mountains, China, is in a deep water facies (personal communication, Zhou Zhiyi, Oct. 1984). Thus a fairly deep shelf environment for the Raheen fauna seems likely.

Age

A late Caradoc to early Ashgill age was suggested for the Raheen Group by Williams (*in* Williams *et al.* 1972: 58). *Tretaspis ceryx* is very close to *T. ceriodes* Angelin (see Owen 1980), which is restricted to latest Caradoc units in Britain and Scandinavia. Similarly *Platylichas laxatus* occurs in several late Caradoc units in these areas, and the Raheen species of *Primaspis* is close to *P. caractaci* from the upper Caradoc of south Shropshire; thus the closest ties of the trilobite fauna are with the upper Caradoc. This is broadly supported by graptolites which have been examined by Dr R. B. Rickards of Cambridge University. He informs us that the presence of a climacograptid reminiscent of *Climacograptus caudatus* Lapworth and of a specimen of ?*Lasiograptus harknessi* Nicholson tentatively suggests the *Dicranograptus clingani* Zone.

Systematic palaeontology

The terminology adopted herein is largely that used by Harrington *et al. in* Moore (1959), except that of the trinucleids, which follows Hughes *et al.* (1975), and a few terms introduced since 1959 the origins of which are indicated in the text. The occipital ring is considered part of the glabella. All angles are expressed to the nearest 5° and percentage ratios to the nearest 5%.

The descriptions are based largely on our own collections but existing museum material has also been examined. Some of the older collections and literature citations involve some confusion or ambiguity as to the horizon from which specimens were collected, material from the Raheen Formation being confused with specimens from the Tramore Limestone. Where there is doubt, specimens have not been used for descriptive purposes and citations omitted from synonymy lists. The indeterminate species of *Remopleurides* (Fig. 15), *Illaenus* (Fig. 12), *Harpidella* (s.l.) (Fig. 9) and a harpid (Figs 10–11) in our collections are too poorly preserved to warrant description or discussion but are illustrated for the sake of completeness.

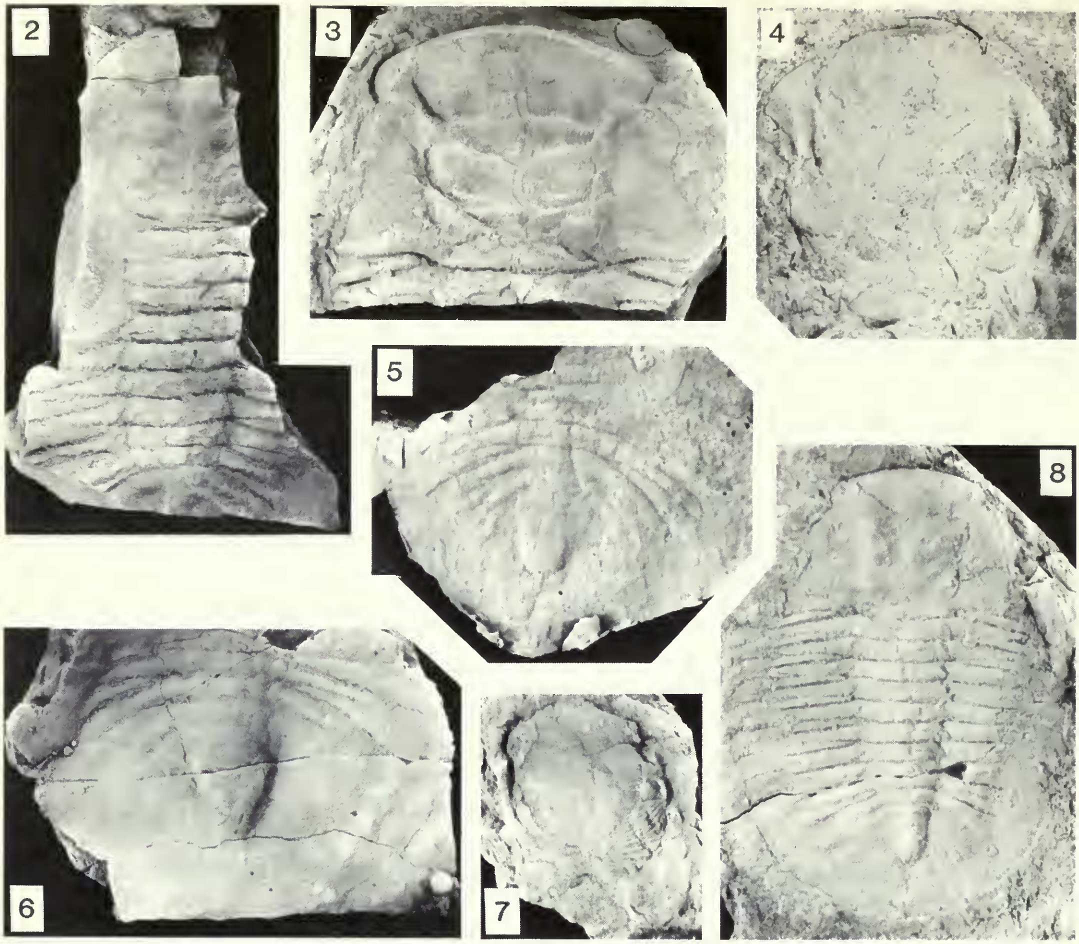
Family **NILEIDAE** Angelin, 1854

Genus ***HOMALOPTEON*** Salter, 1866

TYPE SPECIES. Subsequently designated by Vogdes, 1925; *Ogygia Portlockii* Salter, 1849: 1–4; pl. 7, figs 1–2, 6–7. From the Raheen Formation (upper Caradoc) at Newtown Head, Co. Waterford.

Homalopteon portlockii (Salter, 1849)
Figs 2–8

1843 *Asaphus dilatatus* (Dalman); Portlock: 293; pl. 24, fig. 3.
1848 *Ogygia dilatata* (Dalman); Phillips: 239.
1849 *Ogygia Portlockii* Salter (*pars*): 1–4; pl. 7, figs 1–2, 6, 7 (*non* figs 3–5, 3*–5*, = *Homalopteon radians* (M'Coy); see Whittard 1961: 227).



Figs 2–8 *Homalopteon portlockii* (Salter). Fig. 2, **lectotype** herein selected; BGS GSM266, dorsal view of internal mould of articulated specimen, × 0·9. Original of Salter (1849: pl. 7, figs 1, ?2; 1866: pl. 19, fig. 6). Fig. 3, BGS GSM35312, dorsal view of internal mould of cranidium, × $1\frac{1}{4}$. Original of Salter (1866: pl. 19, fig. 9). Fig. 4, It.17465, ventral view of hypostoma, × 3, sample 3. Fig. 5, SM A16151, dorsal view of latex cast of pygidium, × 1. Fig. 6, BGS GSM35311, dorsal view of internal mould of pygidium, × 0·9. Original of Salter (1866: pl. 19, fig. 8). Fig. 7, BGS GSM35313, ventral view of partially exfoliated hypostoma, × $1\frac{1}{2}$. Original of Salter (1866: pl. 19, fig. 10). Fig. 8, BGS GSM35310, dorsal view of internal mould of specimen lacking free cheeks, × 2. Original of Salter (1866: pl. 19, fig. 7). Raheen Formation. See p. 95.

non 1852 *Ogygia Portlockii* Salter; Barrande: 259, 271–272 (= *Homalopteon radians* (M'Coy); see Whittard 1961: 227).
1866 *Barrandia* (*Homalopteon*) *Portlockii* (Salter) Salter: 138–140; pl. 19, figs 6–10.
1899 *Barrandia Portlockii* (Salt.); Reed: 723.
1931 *Homalopteon portlockii* (Salter) Reed: 468.
1973 *Barrandia portlockii* (Salter); Hughes: fig. 3(4); p. 12.
1980 *Homalopteon portlockii* (Salter); Baird: 25.

Lectotype. Here selected: BGS GSM266, an incomplete articulated specimen, original of Salter 1849: pl. 7, figs 1, ?2 and 1866: pl. 19, fig. 6. Fig. 2.

MATERIAL. Specimens of all but the free cheek of this species are present in our samples but are poorly preserved; the following description is based largely on the specimens illustrated by Salter (1849, 1866).

DESCRIPTION. Complete specimen oval in outline, maximum width half sagittal length.

Cranidium parabolic, sagittal length about two-thirds of posterior width. Glabella parallel-sided over its posterior two-thirds, in front of which it expands to 170% of its occipital width. Occipital ring lenticular in outline, sagittal length 20% of maximum width, defined anteriorly by a shallow but distinct occipital furrow. Four pairs of glabellar furrows present but as all the available cranidia show some degree of crinkling their precise development is not clear. S1 parallel proximally, turning abaxially through 90°. S4 situated just in front of the level where the glabellar expansion begins. None of furrows extend to axial furrow. Anterior part of glabella steeply declined, although this feature is commonly accentuated diagenetically. Axial furrows broad (tr.) and shallow. Fixed cheeks triangular in outline. Posterior borders moderately swollen (exsag.), transversely directed and tapering abaxially. Posterior border furrows broad and shallow, directed abaxially rearwards at a high angle to the sagittal line. Palpebral lobes crescentic, extending from a level a short distance behind S3 to a short distance in front of S4 where they abut the frontal lobe of the glabella. Free cheeks not known.

Hypostoma gently swollen (tr., sag.), very slightly longer than wide. Median body oval in outline, extending to anterior margin, defined laterally by deep furrows, and by a gentle break in slope posteriorly. Anterior wings short (tr.) but distinct. Lateral border narrow, posterior border long (sag., exsag.), flat-lying. External surface of hypostoma bearing closely-spaced terrace lines which step down forwards. With the exception of those on the anterior part of the median body, which are essentially transversely directed, the terrace lines curve in arcs which are concave forwards.

Thorax of eight segments, slightly barrel-shaped. Axis weakly swollen, occupying approximately 30% of the width of each segment, tapering very gently rearwards. Anterior and posterior edges of each axial ring very gently convex rearwards. Axial furrow no more than a slight break in slope. Pleurae transversely directed with fulcrum situated at about two-thirds of length from axis. Pleural furrow directed abaxially rearwards at a high angle to the sagittal line, dying out distally. Tips of pleurae tapered with the anterior edge curving sharply rearwards and the posterior edge deflected more gently rearwards. Closely spaced terrace lines, stepping down abaxially, developed on outer parts of pleurae, approximately parallel to the sagittal line.

Pygidium semicircular in outline in smaller specimens but sagittal length increasing to about two-thirds of maximum width in larger pygidia. Axis occupies 25% of the maximum width and 60–65% of the sagittal length of the pygidium; gently convex (tr.) anteriorly, more strongly so posteriorly. Behind the round-ended axis is a short, narrow (tr.) post-axial ridge. Four well-developed axial rings present (n = 4) and up to a further three can be discerned in addition to a short terminal piece. Three distinct pleural ribs present (n = 4) and a fourth is much less well developed. Pleural and interpleural furrows broad and shallow, dying out abaxially. Surface of outer parts of pygidium bears concentric terrace lines which step down rearwards. These are very weakly developed anteromesially.

DISCUSSION. The history of the familial assignment of *Homalopteon* was summarized by Hughes (1979: 162, 164), who discussed its distinction from *Barrandia* M'Coy, 1849. The redescription here of the type species, *H. portlockii*, confirms Hughes' conclusions. *H. portlockii* differs from *H. radians* (M'Coy, 1849) from the uppermost lower Llandeilo of Builth, central Wales, and possibly the lower Llanvirn of Shelve (see Hughes, 1979 for revision), primarily in the pygidium having more axial rings (4–7 as against 2–4) and pleural ribs (3 distinct and 1 weak as against 1 distinct and 1 weak). The glabella may be more strongly expanded frontally, the glabellar furrows may be more deeply impressed and the outline of the fixed cheek may be slightly different in the Irish species, but these may all reflect differences in preservation. As noted by Hughes (1979: 171) *H. murchisoni* Hughes, 1979 from the Llandeilo (*gracilis* Zone) of Builth is morphologically intermediate between *H. radians* and *H. portlockii.*

Family **PROETIDAE** Salter, 1864

Subfamily **TROPIDOCORYPHINAE** Přibyl, 1946

Genus ***DECOROPROETUS*** Přibyl, 1946

TYPE SPECIES. Original designation by Přibyl, 1946; *Proetus decorus* Barrande, 1846: 64. From the Liteň Formation (Wenlock), Lodenice, Prague district, Czechoslovakia.

Decoroproetus sp.
Figs 13–14

MATERIAL. Only two cranidia and one pygidium, all incomplete, are known.

DISCUSSION. Although the anterior border and fixed cheeks are poorly preserved, the distinct anterior constriction of the glabella invites comparison with *D. calvus* (Whittard) and *D. piriceps* (Ingham) from the Caradoc (Soudleyan to ?Actonian) and lower Ashgill respectively. These British species were redescribed by Owens (1973) and the age of some of the units containing *D. piriceps* recently reviewed by Price (1984). The marked abaxial taper of the occipital ring, the more tapered posterior part of the pygidial axis and the greater number of pleural furrows which are also more deeply incised distally distinguish the Raheen form from these species.

Family **DIMEROPYGIDAE** Hupé, 1953

Subfamily **MESOTAPHRASPIDINAE** Jaanusson, 1956

Genus ***MESOTAPHRASPIS*** Whittington & Evitt, 1954

TYPE SPECIES. Original designation; *Mesotaphraspis parva* Whittington & Evitt, 1954: 46–48; pl. 3, figs 1–36; pl. 4; text-fig. 11. From the Edinburg Limestone (Middle Ordovician) of Virginia, U.S.A.

Mesotaphraspis sp. nov.
Fig. 16

MATERIAL. A single external mould of a cranidium.

DESCRIPTION. Glabella occupies 70% of sagittal length of cranidium and has a maximum width directly in front of occipital furrow equal to 80% of its sagittal length. Occipital ring tapering strongly over its outer two-thirds, bearing a median tubercle. Occipital furrow transversely directed. Remainder of glabella tapering gently forwards, rounded frontally. S1 and S2 marked by shallow indentations. Axial furrow deep. Preglabellar field long (sag., exsag.), bearing a large triangular median pit in front of deep preglabellar furrow. Anterior border furrow well incised, curving in a gentle arc convex forwards. Anterior border broad (sag., exsag.). Inner parts of fixed cheeks narrow (tr.), defined abaxially by long (exsag.), deep palpebral furrows which converge forwards slightly. Posterior branch of facial suture approximately transversely directed; anterior branch curves abaxially for a short distance before being directed forwards at about 35° to the sagittal line. External surface of cranidium densely covered in coarse granules.

DISCUSSION. The narrow (tr.) inner parts of the fixed cheeks distinguish this specimen from all other described species of *Mesotaphraspis*, but until more material is available a new species is not formally established. It is closest to *M. inornata* Whittington & Evitt (1954: 48; pl. 24, figs 1–39) from the Lincolnshire Limestone (lower Caradoc?) of Virginia. However, in addition to the broader inner fixed cheek, the American species has the occipital ring only gently tapered distally.

Family **TRINUCLEIDAE** Hawle & Corda, 1847

Subfamily **TRINUCLEINAE** Hawle & Corda, 1847

Genus ***TRETASPIS*** M'Coy, 1849

TYPE SPECIES. Subsequently designated by Bassler, 1915: 1285; *Asaphus seticornis* Hisinger, 1840: 3; pl. 37, fig. 2. From the Fjäcka Shale Formation (Pusgillian) of Dalarna, Sweden.

Tretaspis ceryx Lamont, 1941
Figs 29–40

1899 *Trinucleus hibernicus* Reed (*pars*): 723.
1939 *Tretaspis* cf. *cerioides* (sic) (Angelin); Lamont *in* Stubblefield: 59
1939 *Tretaspis* cf. *cerioides* (sic) (Angelin); Lamont: 173.
1941 *Tretaspis ceryx* Lamont: 459–463; pl. 5, figs 10–14.
non 1953 *Tretaspis ceryx* Lamont; Lamont: 433 [= *Broeggerolithus* sp.].
1975 *T. ceryx* Lamont; Hughes *et al.*: 564.
1980 *Tetraspis* (sic) *ceryx* Lamont; Tunnicliff: 45.
1980 *Botrioides hibernicus* (Reed); Baird: 7 (*pars*, Newtown Head specimens only).
1980 *Tretaspis* sp.; Baird: 52 (*pars*, Newtown Head specimens only).
1981 [generically undetermined] *ceryx* Lamont; Temple: 220; table 1; fig. 9.

LECTOTYPE. Selected by Temple (1981: 220); BU 297a, an almost complete internal mould, lacking the upper lamella of the fringe.

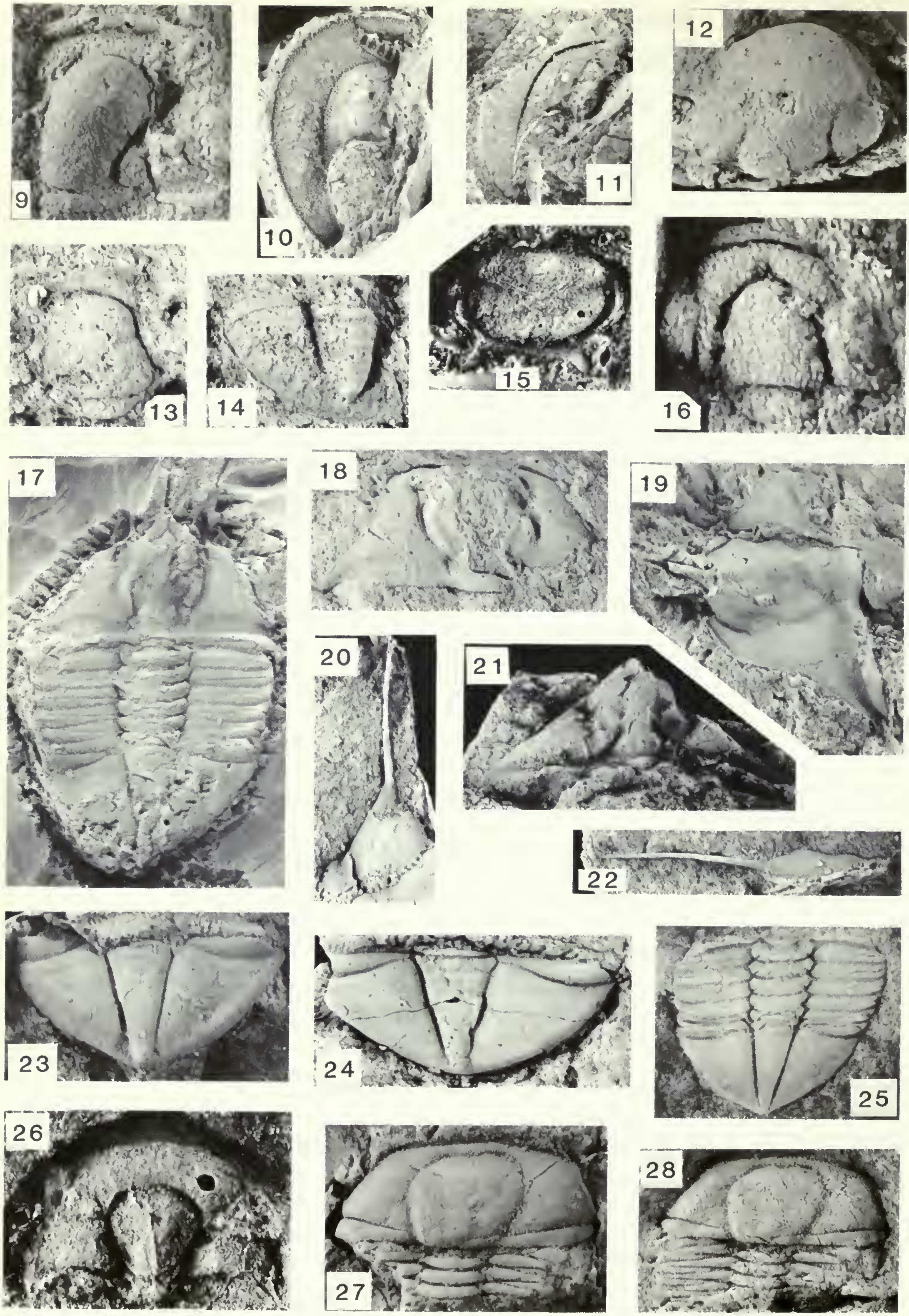
MATERIAL. Complete and disarticulated specimens of this species constitute the most abundant trilobite remains in the Raheen Formation (51% of the material sampled).

DIAGNOSIS. *Tretaspis* of the *T. moeldenensis* group with arcs E_{1-2}, I_{1-2}, I_n complete and I_3 almost invariably complete. No other arcs developed. Arcs I_1, E_{1-2} in deep, slot-like sulci over the whole fringe. External surface of glabella and genal lobes strongly reticulate. Six to seven deep pygidial apodemal pits.

DESCRIPTION. Occipital ring arched strongly rearwards and upwards. Occipital furrow shallow. Glabella between occipital ring and pseudofrontal lobe narrow and strongly convex (tr.) mesially, very weakly so laterally where the composite lateral glabellar lobe is barely discernible. S1 and S2 shallow on the external surface, deeper on internal moulds. Pseudofrontal lobe subspherical, bulbous and overhanging part of the fringe, occupying approximately 65% of the sagittal glabellar length. Median node situated slightly behind the highest part of the glabella. Axial furrows broad and shallow. Genal lobes quadrant-shaped, gently inclined from dorsal and posterior border furrows, outer parts steeply declined. Lateral eye tubercles located on the posterior parts of the genal lobes, small, more distinct on internal mould than external surface. Weak eye ridges diverge rearwards at about 120° from very shallow S3; only visible on internal mould. External surface of glabella and genal lobes bears a strong, coarse reticulation which is much more subdued on internal moulds. Furrows smooth, as is the ridge-like posterior border. Length of genal spines not known. Inner parts of fringe steeply declined, outer part more gently so.

Pit arcs E_{1-2}, I_{1-2} and I_n complete; I_3 lacks a few pits posteriorly in only one out of 109 specimens. Pits arranged in a single set of radii with those in arcs E_{1-2} and I_1 sharing deep slot-like sulci at least to the zone of complication if not to the posterior border. Weak lists developed on both sides of I_2. As Fig. 29 (p. 102) shows, there are 20–26 pits in E_1 (half fringe; $n = 41$, $\bar{x} = 23\frac{1}{2}$, S.D. $= 1\frac{1}{2}$), $17\frac{1}{2}$–$23\frac{1}{2}$ ($n = 33$, $\bar{x} = 20\frac{1}{2}$, S.D. $= 1\frac{1}{2}$) in I_n and 6–9 ($n = 84$, $\bar{x} = 8$, S.D. $= 1$) along the posterior margin of the fringe. Arc E_2 contains one less pit than E_1 in 98 out of 105 specimens; 5 specimens show the same number in both arcs and single specimens are known with two and three pits fewer in E_2. One specimen (Fig. 35) shows an indentation in the posterolateral part of the fringe affecting the outer three arcs of pits. This is similar to the damage reported by Owen (1983) in several other trinucleids.

Thorax very slightly barrel-shaped. Convex (tr.) axis occupies approximately 25% of the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width of each segment. Axial furrow very shallow. Posterior pleural band ridge-like, tapering abaxially a little. Pleural furrow broad (exsag.). Very narrow anterior band expands very slightly at the fulcrum which lies only a short distance in from the pleural tip.

Length of sub-semicircular pygidium increases from about 25% to about 30% of the maximum pygidial width over the size range present in the sample. Axis weakly convex (tr.) anteriorly, progressively less so posteriorly in which direction it tapers at about 30°. Six or seven ($n = 13$) pairs of deep apodemal pits present along axis; up to three very shallow pits/scars can also be distinguished in a few specimens. Anterior axial ring continuous with a strong ridge on the pleural fields and up to three very much fainter ridges may also be present. Border of pygidium broad and very steeply declined. Details of terrace line pattern not known.

DISCUSSION. The similarity of *T. ceryx* to *T. ceriodes* (Angelin) was noted by Lamont (1941: 462) and Ingham (1970: 53), with Owen (1980: 722) suggesting that the Irish form may best be regarded as a geographical subspecies of *T. ceriodes*. Angelin's species from upper Caradoc (Actonian and Onnian) units in Sweden, Norway and Britain is extremely variable in its fringe pit distribution and Owen (1980: 719–723; pl. 89; text-fig. 2) defined four 'morphs' in the Norwegian *T. ceriodes angelini* Størmer. Owen argued on the basis of the syntypes of *T. ceryx* that the Raheen form differed from his *T. ceriodes angelini* morph C only in its extensive, deep I_1, E_{1-2} sulcation. The larger sample of *T. ceryx* now available, however, enables further distinctions to be made. As Fig. 29 shows, the ranges of variation in both the E_1 and I_n arcs overlap but with *T. ceryx* having a higher mean in each case ($23\frac{1}{2}$ as against 21 in E_1; $20\frac{1}{2}$ as against $18\frac{1}{2}$ in I_n). Chi-squared tests on the radius number of the posterior pit in these arcs show that the two forms are significantly different at the 1% confidence level. Moreover, whereas only one specimen out of 109 in *T. ceryx* has I_3 incomplete posteriorly, 32 out of 39 have this condition in *T. ceriodes angelini* morph C. Thus whilst *T. ceryx* is close to *T. ceriodes*, its specific status is here retained.

Fig. 9 *Harpidella* (s.l.) sp. It.19438, dorsal view of latex cast of distorted cranidium, × 12. Raheen Formation, sample 3. See p. 95.

Figs 10–11 Harpid, gen. et sp. indet. Fig. 10, It.19439, dorsal view of latex cast of cephalon, × $3\frac{1}{2}$, sample N. Fig. 11, It.15998, dorsal view of internal mould of incomplete cephalon, × 2, sample 3. Raheen Formation. See p. 95.

Fig. 12 *Illaenus* sp. It.19440, palpebral view of internal mould of cranidium, × 5. Raheen Formation, sample 3. See p. 95.

Figs 13–14 *Decoroproetus* sp. Fig. 13, It.17458, dorsal view of internal mould of incomplete cranidium, × 7. Fig. 14, It.19441, dorsal view of internal mould of incomplete pygidium, × 6. Raheen Formation, sample 3. See p. 98.

Fig. 15 *Remopleurides* sp. It.19442, ventral view of latex cast of hypostoma, × $7\frac{1}{2}$; note that the overall morphology conforms to that of the *R. eximius* species group as defined by Tripp (1980: 125). Raheen Formation, sample 3. See p. 95.

Fig. 16 *Mesotaphraspis* sp. nov. It.17459, dorsal view of latex cast of cranidium, × 18. Raheen Formation, sample 3. See p. 98.

Figs 17–25 *Ampyx austinii* Portlock. Fig. 17, **neotype** herein designated; BM(NH) It.17432, dorsal view of specimen lacking free cheeks, × $1\frac{1}{2}$, sample 4. Fig. 18, It.19443, dorsal view of cranidium lacking most of glabella, × $2\frac{1}{2}$, sample 3. Fig. 19, It.19444, oblique anterolateral view of cranidium with damaged glabellar spine, × 3. Fig. 20, It.19445, dorsal view of latex cast of incomplete cranidium, × 2, sample 3. Fig. 21, It.19446, dorsal view of distorted cranidium, × 2, sample 3. Fig. 22, It.19447, lateral view of latex cast of incomplete free cheek, × 2, sample 4. Fig. 23, SM A16147, dorsal view of latex cast of pygidium, × 3. Fig. 24, It.19448, dorsal view of pygidium, × 2, sample 4. Fig. 25, It.17478, dorsal view of articulated thorax and pygidium, × 2, sample 3. Raheen Formation. See p. 103.

Fig. 26 *Yumenaspis* sp. Dorsal view of latex peel of plasticine cast of cranidium formerly in the Murphy collection but now lost, × $6\frac{1}{2}$. Raheen Formation. See p. 106.

Figs 27–28 *Salteria involuta* Salter. Holotype. Fig. 27, BGS GSM35713, dorsal view of cephalon and anterior part of thorax, × 4. Fig. 28, dorsal view of plasticine cast of counterpart to the holotype specimen, now lost, × $3\frac{1}{2}$. Raheen Formation. See p. 106.

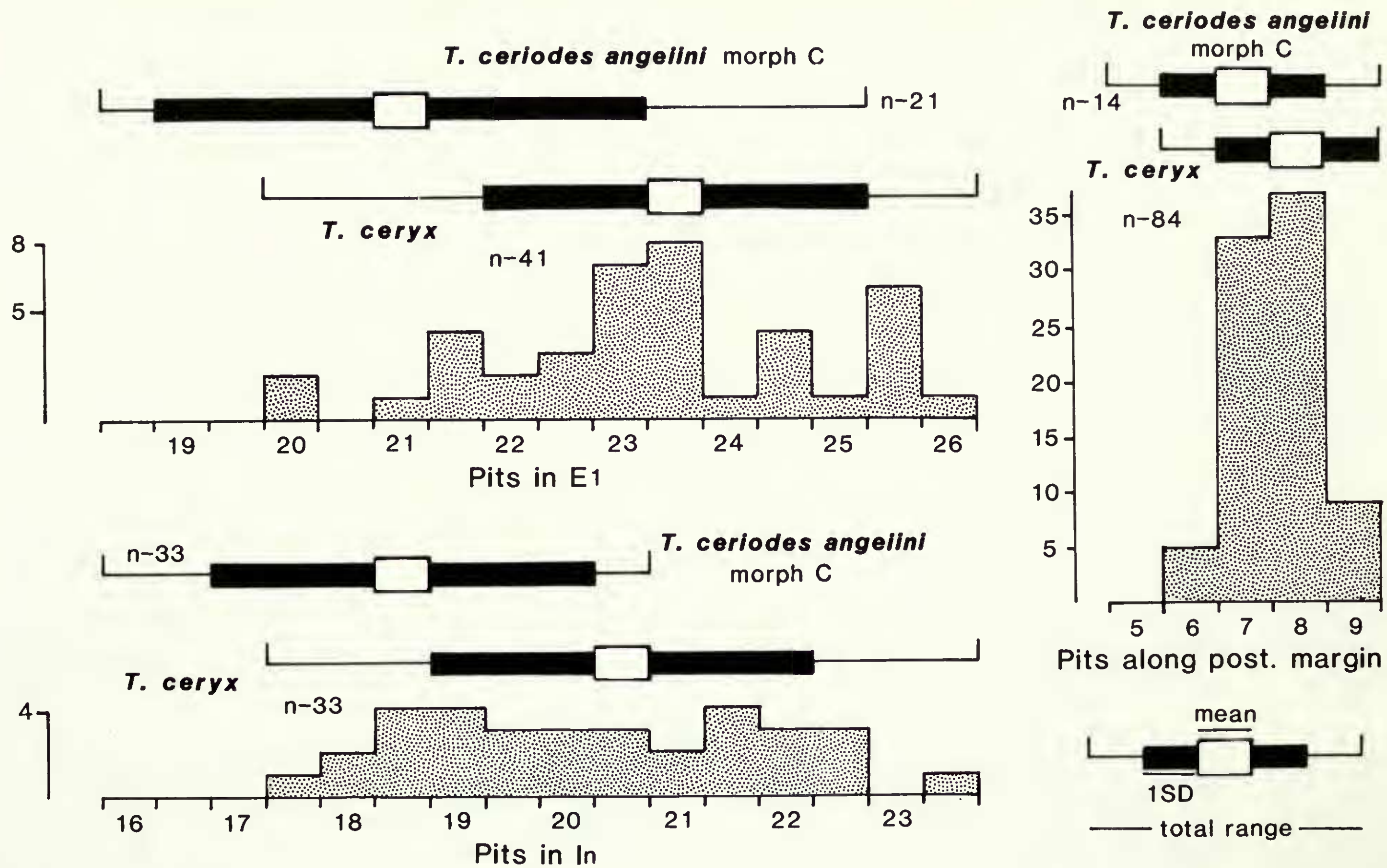


Fig. 29 Histograms showing the variation in selected fringe characters in *Tretaspis ceryx* Lamont and a comparison with the range, mean and one standard deviation each side of the mean in *T. ceriodes*-(Angelin) *angelini* Størmer morph C (see Owen 1980: fig. 2). Half-fringe values are given for the number of pits in E_1 and I_n. The number of pits along the posterior margin of the fringe excludes the posterior fossula.

The complete I_3 arc and slot-like I_1, E_{1-2} sulci of *T. ceryx* are also seen in most specimens in the topotype sample of *T. colliquia* described by Ingham (1970) from Pusgillian strata in the Murthwaite Inlier in northern England. Ingham's species was subsequently considered a subspecies of *T. moeldenensis* Cave (Price 1977: 764–770). One of Ingham's eleven original specimens has a short I_4, and two have I_3 incomplete mesially. The two specimens where the E_1 arc can be counted have 28 pits in the half-fringe whereas the maximum number in *T. ceryx* is 26, seen in one of the 41 specimens. *T. moeldenensis colliquia* also differs in having smooth genal lobes, a smooth or very subdued reticulation on the glabella and in having ten (as against six or seven) deep pygidial apodemal pits. *T. moeldenensis moeldenensis* from the lower Ashgill of Wales has an extensive I_4 arc development and a high E_1 pit count (Price 1977: fig. 1). Price (1977: 766–770) has also described samples from the lower Ashgill of Wales which he interpreted as reflecting a continuum between the topotypes of the end-member subspecies of *T. moeldenensis*. *T. caritus* Price, 1981 from the lower Rawtheyan of Wales and northern England has slot-like I_1, E_{1-2} sulci, a complete I_3 arc and seven pairs of pygidial apodemes. It differs from *T. ceryx*, however, primarily in commonly having arc I_4 developed (11 out of 15 specimens), 11–12 (as against 6–9) pits along the posterior border of the fringe, distinct lists between all the I arcs, smooth genal lobes and reticulation restricted to the posterior part of the glabella.

Lamont (1953: 433) suggested that trinucleid material in the Royal Scottish Museum, Edinburgh from Longvillian shales at Slieveroe, Co. Wicklow may be a variety of *T. ceryx*, but recent examination of this poorly preserved material shows it to belong in *Broeggerolithus*. Moreover, Brenchley *et al.* (1977: 73, 82–3; pl. 1, figs 7–9) have described specimens from there as *B.* cf. *nicholsoni* (Reed). These latter authors also recorded *T.* cf. *ceryx* from Harnagian or Soudleyan strata at Greenville, Enniscorthy, Co. Wexford. Specimens in the Griffith Collection, National Museum of Ireland, from here almost certainly belong in *Broeggerolithus*. Specimens collected by Brenchley *et al.* now housed in Trinity College, Dublin, however, are of a *Tretaspis* very close to *T. ceryx* (see Fig. 41). The material is too incomplete for confident determination but it suggests the faunal list given by Brenchley *et al.* (1977: 70) may include species from different stratigraphical levels.

Family **RAPHIOPHORIDAE** Angelin, 1854

Subfamily **RAPHIOPHORINAE** Angelin, 1854

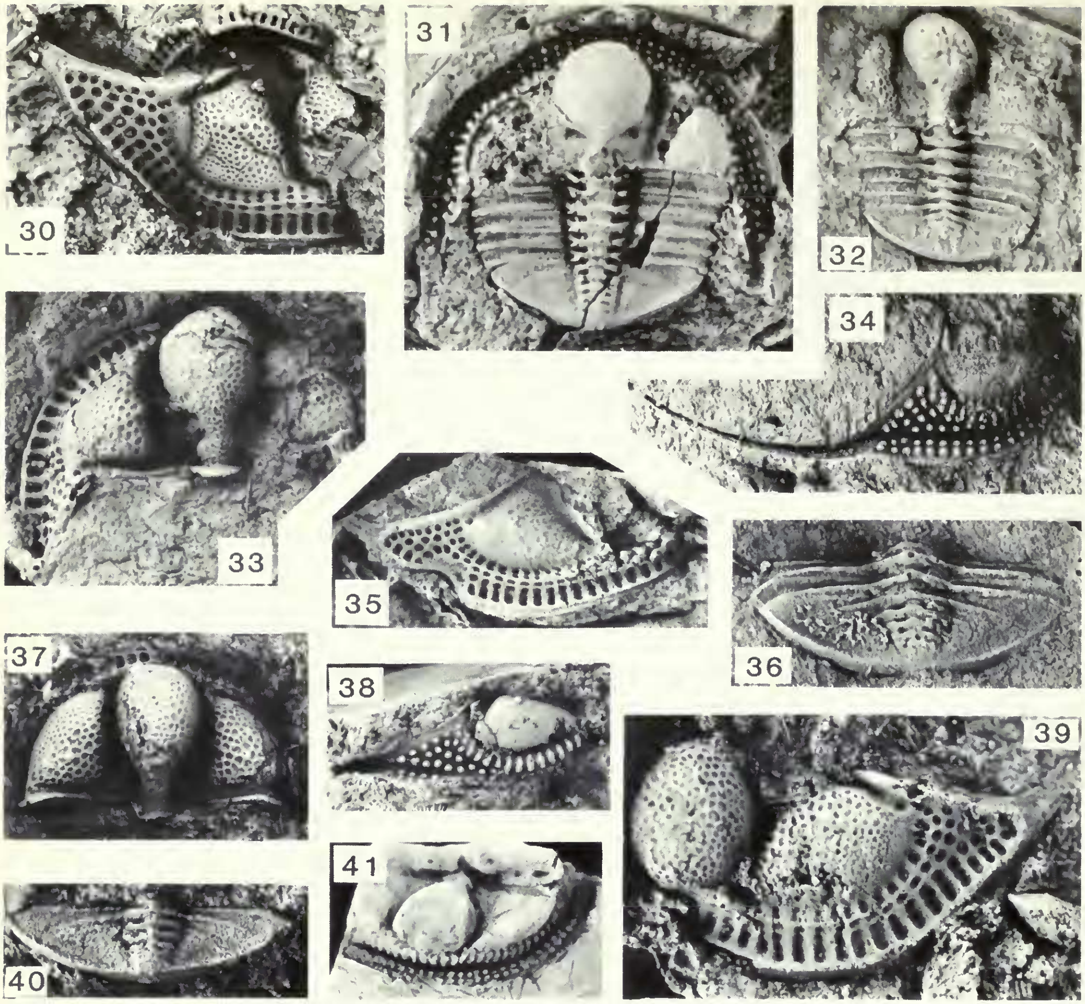
Genus ***AMPYX*** Dalman, 1827

Type species. By monotypy; *Asaphus* (*Ampyx*) *nasutus* Dalman, 1827: 53; pl. 5, fig. 3. From the upper Arenig of Sweden.

Ampyx austinii Portlock, 1843
Figs 17–25

1843 *Ampyx Austinii* Portlock: 261–262; pl. 1B, figs 1, 2.
1899 *Ampyx mammillatus* (sic) Sars; Reed: 723.
?1899 *Ampyx costatus* Sars; Reed: 723.
1940 *Ampyx mammillatus* (sic) Sars var. *austini* Portlock; Whittard: 157; pl. 5, fig. 4.
?1977 *Ampyx austini* Portlock; Brenchley *et al.*: 70, 82.
1980 *Ampyx linleyensis* Whittard; Baird: 3 (*pars*, Newtown Head specimens only).

Neotype. A lectotype for *A. austinii* was chosen by Whittard (1940) but was destroyed during an air raid in Liverpool in 1941 (Whittard 1955: 29; personal communication Mr P. W. Phillips, Merseyside City Museums, 1981). The specimen closely conformed to the illustration on Portlock's (1843) plate 1B, fig. 2. Whittard (1940: 168) also suggested that the dorsal shield BGS GSM 35324 might be the original of Portlock's plate 1B, fig. 1 but Tunnicliff (1980: 54) noted that there is no evidence for this conclusion. There is also ambiguity as to the type horizon of *A. austinii*. Portlock (1843: 262) stated that the specimens were collected by Austin at Tramore but Whittard's lectotype was labelled 'Newtown Head' and thus was assumed by



Figs 30–40 *Tretaspis ceryx* Lamont. Fig. 30, BU 298, anterolateral view of latex cast of distorted cephalon, $\times 3\frac{1}{2}$. Cast of original of Lamont (1941: pl. 5, fig. 11). Fig. 31, lectotype, BU 297a, dorsal view of internal mould of specimen lacking upper lamella of fringe, $\times 2\frac{1}{2}$. Original of Lamont (1941: pl. 5, fig. 10). Fig. 32, It.17457, dorsal view of latex cast of articulated specimen, $\times 4\frac{1}{2}$, sample 3. Fig. 33, RSM Geol. 1870.12.864, dorsal view of latex cast of cranidium, $\times 3\frac{1}{2}$. Fig. 34, It.19449, lateral view of posterior lower lamella and spine, $\times 3\frac{1}{2}$, sample 3. Fig. 35, It.17052, anterolateral view of latex cast of cephalon showing indented fringe, $\times 3\frac{1}{2}$, sample 3. Fig. 36, It.19450, dorsal view of latex cast of pygidium and posterior two thoracic segments, $\times 4\frac{1}{2}$, sample 5. Fig. 37, RSM Geol. 1870.12.1335, dorsal view of latex cast of cranidium, $\times$ 5. Fig. 38, RSM Geol. 1870.12.1344, lateral view of internal mould of cephalon lacking upper lamella of fringe, $\times$ 2. Fig. 39, SM A16156, oblique anterolateral view of latex cast of cephalon, $\times 6\frac{1}{2}$. Fig. 40, It.19451, dorsal view of latex cast of pygidium, $\times$ 5, sample 5. Raheen Formation. See p. 99.

Fig. 41 *Tretaspis* cf. *ceryx* Lamont. TCD 20047, oblique anterolateral view of internal mould of cephalon lacking upper lamella of fringe, $\times 1\frac{1}{2}$. Caradoc strata near Greenville, Enniscorthy, Co. Waterford. See p. 103.

Whittard (1940: 20; 1955: 20) and Lamont (1941: 462–463) to have come from the Raheen Shales. The possibility that they were from the Tramore Limestone, which certainly contains an *Ampyx* close to if not conspecific with that in the Raheen Formation, cannot be excluded completely. As there is no extant type material, in order to stabilize the species a neotype (BM (NH) It.17432) from the Raheen Formation (Sample 3) is designated herein. Fig. 17.

Material. This is the second most abundant species in the Raheen fauna, comprising 26·6% of the trilobite remains sampled. Although present, free cheeks and hypostomata are rare and are less well known than the other skeletal elements.

Description. Cranidium (excluding spines) slightly shorter (sag.) than half its posterior width. Glabella gently convex posteriorly, a little more strongly so anteriorly; extending in front of cheeks and bearing an anterior spine of circular cross section and unknown length. A very weak carina is present in a few specimens. Long bacculae (see Fortey 1975: 15) developed, each defined adaxially by a shallow portion of the axial furrow and abaxially by a baccular furrow which is convex outwards and becomes shallower rearwards. Maximum width of glabella at (and including) bacculae approximately equal to that in front of bacculae. Occipital ring tapering gently abaxially, defined anteriorly by a broad, shallow furrow. In front of this occipital furrow the glabella tapers markedly forwards where it is separated from the posterior part of each baccula by a deep portion of the axial furrow. A generally weakly swollen glabellar lobe is developed adjacent to the anterior part of the baccula. It is confluent with the glabellar stem posteromesially but defined anteromesially by a deep furrow which is directed forwards at about 45° to the sagittal line and dies out abruptly both anteriorly and posteriorly. Axial furrow deep adjacent to frontal lobe of glabella. Fixed cheeks subtriangular in outline. Posterior border ridge-like, transversely directed over most of its length, curving rearwards and expanding slightly distally. Posterior border furrow shallow and very broad (exsag.). Facial suture sinuous, directed adaxially forwards at 50° to the sagittal line to opposite the mid parts of the bacculae, curving abaxially through 30° before turning sharply adaxially and becoming almost transversely directed. Available free cheeks and hypostomata too poorly preserved for adequate description.

Maximum width of thorax at second and third segments. First segment slightly longer (sag., exsag.) than the others and tapering markedly distally whereas the remainder are blunt-ended. Axis occupies 30% of the thoracic width anteriorly, tapering to 25% posteriorly. Axial rings moderately convex (tr.) with lobe-like swellings adjacent to the well-incised axial furrows. Pleurae flat-lying, transversely directed. Broad (exsag.) pleural furrow tapers slightly at the distal end of the first segment, but maintains its width on the other segments where it curves very gently forwards distally.

Pygidium triangular in outline with a sagittal length ranging from about 40% to about 50% of the maximum width. Axis occupies 20–25% of the anterior width and tapers rearwards at 50–60°. Lenticular articulating half-ring short (sag.). Up to five weak axial rings may be discerned in some specimens but many show no segmentation of the axis. Axial furrow deep and narrow. A single deep furrow is present on the pleural area extending in a broad arc convex rearwards, from the anterolateral corner of the axis to the lateral border a short distance behind the anterior corner of the pygidium. Border of pygidium steeply declined, not visible in dorsal view.

Discussion. Whittard (1955: 18–21) suggested that *Ampyx austinii* might be synonymous with his own species, *A. linleyensis*, from strata belonging to the Llanvirn *Didymograptus bifidus* Zone at Shelve in the Welsh Borderland. He considered differences in the glabella between the Shropshire and Irish forms noted by Lamont (1941: 463) to be minor, perhaps with the exception of the narrower (tr.) glabellar stem of *A. austinii*. In addition, however, the absence of both principal genal veins and deeply incised furrows on the pygidial axis also serve to distinguish the Irish species.

Preliminary analysis of specimens from the Tramore Limestone suggests that *A. austinii* may be present and would indicate a long stratigraphical range for the species. Brenchley *et al.*

(1977) recorded *A. austinii* from the probable Caradoc strata at Greenville, Enniscorthy, Co. Wexford. The fauna here is in need of modern taxonomic study, but the presence of a trinucleid similar to the Raheen *Tretaspis ceryx* (see above) suggests that at least one horizon at Greenville may correspond to the Raheen Formation.

A. austinii differs from the type species *A. nasutus* (redescribed by Whittington, 1950) primarily in the presence of bacculae and hence the glabella does not expand evenly forwards as it does in this Arenig species. A revision of the Norwegian Ordovician raphiophorids being undertaken by Owen should clarify the relationships of *A. austinii* to the Scandinavian forms.

Subfamily **ENDYMIONIINAE** Raymond, 1920

Genus ***SALTERIA*** Wyville Thomson, 1864

Type species. By monotypy; *Salteria primaeva* Wyville Thomson, 1864: 1 of pl. 6. From the Balclatchie Group (lower Caradoc) of Girvan, south-west Scotland.

Salteria involuta Salter, 1864
Figs 27–28

1864 *Salteria involuta* Salter: 4 of pl. 6.

Holotype. The species is not present in recent collections and is known only from a single specimen in the collections of the BGS (GSM 35713) which is almost certainly the original of Salter. A plasticine cast taken some years ago from an external mould housed with the Murphy Collection in the NMI shows that this was the counterpart of the BGS specimen but the original has now unfortunately been lost.

Description. Smooth, weakly swollen glabella expanding forward to 140% of its posterior width, very gently rounded frontally. Occipital furrow absent; the 'furrow' on the right side of the specimen is a diagenetic fracture. Dorsal and preglabellar furrows weakly impressed. Fixed cheeks smooth, almost flat-lying proximally, outer parts gently declined. Posterior borders expanding gently abaxially over most of their length, tapering distally a little. Posterior border furrows diverging abaxially forward at 165°, in which direction they deepen. Preglabellar area narrow (sag., exsag.). Free cheek and hypostoma not known.

Only the anterior four thoracic segments preserved. Axial rings lenticular, tapering more markedly forwards, abutting posterior band of each pleura at an angle of about 50° to the sagittal line. Pleura transversely directed, crossed by distinct pleural furrow which is directed abaxially rearwards from the anteromesial corner at 80° to the sagittal line. The anterior band therefore expands abaxially whilst the posterior band tapers in this direction. Pygidium not known.

Discussion. A lectotype for the type species of *Salteria*, *S. primaeva* Wyville Thomson, was selected by Tripp (1980: 130), who illustrated other specimens from the lower Balclatchie Group at Girvan and included *S. americana* Cooper, 1953 from the Edinburg Formation in Virginia in its synonymy. *S. involuta* differs from *S. primaeva* in lacking distinct glabellar furrows, in having proportionally broader fixed cheeks and the posterior border not as expanded laterally.

?Family **HAPALOPLEURIDAE** Harrington & Leanza, 1957

Genus ***YUMENASPIS*** Chang & Fan, 1960

Type species. Original designation; *Yumenaspis yumenensis* Chang & Fan, 1960: 135; pl. 9, figs 1–5; text-figs 32–33 (see also Lu *et al.* 1965: 642; pl. 132, figs 1–6). From the middle Ordovician of the Ch'i-lien Mountains, China.

Yumenaspis sp.
Fig. 26

Material. A plasticine cast of a cranidium in the Murphy Collection in the NMI, original now lost.

DISCUSSION. This specimen was discussed briefly by Tripp (1976: 397), who noted that the long preglabellar field is similar to that of the type species *Y. yumenensis* but that the position of the palpebral lobe close to the glabella is similar to the condition in *Y. templei* Tripp, 1976. This last species is from the Lower Llandeilo basal Superstes Mudstones at Girvan. Tripp (1980: pl. 3, fig. 17) later illustrated an indeterminate *Yumenaspis* cranidium from the upper Balclatchie Group (lower Caradoc) at Girvan. The length of the preglabellar field and position of the palpebral lobe resemble these features in the Raheen specimen but detailed comparisons are not possible.

Family **CHEIRURIDAE** Hawle & Corda, 1847

Subfamily **DEIPHONINAE** Raymond, 1913

Genus ***SPHAEROCORYPHE*** Angelin, 1854

TYPE SPECIES. Subsequently designated by ICZN Opinion 614, 1961; *Sphaerocoryphe dentata* Angelin, 1854: 66; pl. 34, fig. 6. From the upper Ordovician of Sweden.

Sphaerocoryphe murphyi sp. nov.
Figs 42–47

?1899 *Sphaerexochus mirus* Beyr.; Reed: 723.

HOLOTYPE. A pygidium (BM(NH) It.19453) from Sample 3. Fig. 44.

MATERIAL. In addition to the holotype, two cranidia, an hypostoma and two pygidia are paratypes. The species comprises 0·8% of the Raheen trilobite fauna.

NAME. For Mr G. J. Murphy who studied the Ordovician rocks of Co. Waterford in the 1950s.

DIAGNOSIS. Species of *Sphaerocoryphe* with two profixigenal spines on the cranidium and strongly divergent posterior pygidial spines.

DESCRIPTION. Sagittal glabellar length equal to approximately half posterior cranidial width (excluding spines). Transverse occipital ring defined anteriorly by a very weakly incised occipital furrow. Basal glabellar lobes gently swollen, circular in outline, situated midway between occipital ring and spherical frontal lobe, which occupies almost two-thirds of the sagittal glabellar length. Dorsal furrows shallow on external surface, deeper on internal mould. Posterior border transversely directed. Broad-based genal spines directed abaxially rearwards at 40° to the sagittal line. Lateral border directed abaxially forwards at 40° to the sagittal line, bearing two robust profixigenal spines; the posterior of these is situated very close to the genal spine. Posterior border furrow shallow proximally, deepening abaxially and confluent with the lateral border furrow. Field of fixed cheek gently swollen (tr., exsag.). Palpebral lobe forwardly placed. External surface of frontal glabellar lobe bears a dense subdued granulation. Rest of external surface too poorly preserved for sculpture to be discerned. Free cheek not known.

Hypostoma trapezoidal in outline. Median body swollen (tr., sag.), slightly longer than wide, defined by broad furrows which are deep laterally but shallow anteriorly and posteriorly. Middle furrow and posterior lobe effaced. Posterior border broad (sag., exsag.) and flat-lying; lateral borders taper forwards and are steeply inclined. Anterior wings transversely directed.

Thorax unknown. Pygidium, excluding spines, sub-semicircular in outline. Axis poorly differentiated from pleural regions, bearing four rings and a triangular terminal piece. Nonfunctional half-rings present behind the first and second axial rings. The anterior two rings are confluent with pleural ribs which broaden abaxially, bear weakly incised furrows proximally and are extended as broad spines. The anterior pair of spines are gently divergent proximally, curving rearwards through about 30° over their outer 40% where they taper markedly. Posterior spines long, very robust, diverging rearwards at 70° proximally, becoming a little more parallel distally. The posterior spines taper evenly and extend to a level behind the posterior border equal to at least twice the sagittal pygidial length. There is a slight break in slope between the first two axial rings and the pleural ribs. No such differentiation is visible on the posterior two rings/ribs which, together with the terminal piece, extend to the broad (sag., exsag.) posterior border which curves in a gentle arc convex rearwards. External surface of pygidium densely covered in fine granules.

DISCUSSION. The most important discriminatory feature is the presence of two profixigenal spines. Other described species sharing this character are: *S. pemphis* Lane, 1971 from the Balclatchie Group (low Caradoc), Girvan district; *S. ludvigseni* Chatterton, 1980 from the Esbataottine Formation (Llandeilo) of the Mackenzie Mountains; *S. thomsoni* (Reed, 1906) from the Upper Drummuck Group (high Rawtheyan), Girvan district; *S.* cf. *thomsoni* (Reed) of Lane, 1971 from the Ashgill Series, Norber Brow, northern England; *S. kingi* Ingham, 1974 from the Rawtheyan Zones 6 and 7 of northern England; and *S.* aff. *kingi* Ingham of Owen, 1981 from horizons of Cautleyan to Rawtheyan age in the Oslo region, Norway. *S. murphyi* differs from these species in its more strongly divergent posterior pygidial spines, and the rounded posterolateral angles of the hypostoma. The closest resemblance is to *S. pemphis*, which it resembles in its large size, robust downturned profixigenal spines, short hypostoma with effaced posterior lobes and long anterior pygidial spines.

Family **ENCRINURIDAE** Angelin, 1854

Subfamily **CYBELINAE** Holliday, 1942

DISCUSSION. The large discrete glabellar lobes and the pygidial ring and rib development suggest an affinity between the Raheen cybeline and species currently placed in *Deacybele* Whittington, 1965. Owen & Romano (*in* Harper *et al.* 1984) have noted that the generic status of Whittington's taxon is questionable, and a preliminary multivariate analysis of the Cybelinae by R. P. Tripp, J. T. Temple & A. W. Owen confirms this. Until this analysis is complete, the Raheen form is not ascribed to an existing genus.

Cybelinae indet., cf. '***Cybele*** ***mchenryi***' Reed, 1899[1]
Figs 49–56

?1846 *Encrinurus stokesii* M'Coy: 47 (*pars*, Newtown Head material only).
cf. 1899 *Cybele McHenryi* Reed: 751; pl. 49, fig. 7.
?1899 *Cybele rugosa* Portl.; Reed: 752.

MATERIAL. Disarticulated examples of all the exoskeletal elements of this species together comprise 3·3% of the trilobite fauna.

DESCRIPTION. Sagittal length of cranidium equal to about 30% of maximum width. Glabella convex (tr.), width across L1 85–90% maximum width across frontal lobe. Occipital ring arched gently forwards mesially, tapering a little distally where it is deflected gently rearwards behind L1 before terminating slightly beyond the level of L1. Mesial part of occipital ring not sufficiently well preserved to determine whether a median tubercle is present or not. Occipital furrow shallow mesially, deepening into an elongate apodeme behind L1. L1 almost square in outline and, with L2, strongly depressed compared with the transversely convex central lobe. S1 deep and pit-like proximally, shallowing and transversely directed towards axial furrow. L2 transversely rectangular in outline, longer (tr.) than L1 but approximately as wide (exsag.). S2 transverse, narrow and deep, expanding (exsag.) proximally and deepening into apodeme. L3 largest of lobes, being about twice as wide (exsag.) as either L1 or L2. Outer edge of L3 directed gently adaxially forwards to sagittal line. S3 directed abaxially forwards at 60°, narrow proximally, broadening slightly before joining axial furrow. Frontal lobe occupies at least 40% of sagittal glabellar length, broadly rounded anteriorly, median pit absent. Preglabellar area not known. Axial furrow broad and shallow; fossula midway between S3 and anterior branch of facial suture. Posterior border ridge-like, transversely directed and expanding only slightly abaxially. Genal spine parallel to sagittal line, length unknown. Posterior border furrow deep

[1] But see Recommendation 21 (a) (I.C.Z.N. 1985: 197). It is not made clear whether this ought to be applied retrospectively.

over most of its length, becoming shallower at genal angle. Field of fixed cheek rising steeply from dorsal and posterior border furrows, extended as a nearly vertical palpebral stalk opposite S2; width across L2 45% width between palpebral lobes. Distinct eye ridge directed from axial furrow at anterior end of L3 to base of palpebral stalk. Details of facial suture not known. Surface of cranidium (including internal mould), excluding furrows, densely granular, granules smallest and densest on palpebral stalk. Three pairs of slightly larger granules distinguishable opposite S2 and two pairs on frontal lobe.

Free cheek convex and steeply downturned. Field broad and gently convex. Lateral border uniformly narrow, 25% maximum width of field. Lateral border furrow broad and shallow, widening but incomplete anteriorly. Details of eye stalk and eye not known. Surface densely and evenly granular, as cranidium.

Hypostoma known from two poorly preserved, incomplete specimens which show a broad similarity to that ascribed to *Deacybele* by Owen & Romano (*in* Harper *et al.* 1984: fig. 58).

Pygidium known in detail only from internal moulds; about as long as maximum width. Axis narrowing abruptly posterior to first ring, then tapering very gently rearwards, extending for 80% length of pygidium; composed of over 20 rings, of which only the anterior is complete on internal mould. Most if not all rings bear small tubercles, sparsely scattered granules on smooth mesial strip of axis. Post-axial ridge comparatively long. Axial furrow moderately deep and narrow for most of length, shallower opposite first ring and posteriorly. Distinct break in slope between convex (tr.) axis and almost flat-lying inner part of pleural area. Pleural lobe composed of four pairs of pleurae. First composed of subequal posterior and anterior bands separated by a strong pleural furrow. Second composed of a strong posterior band and a narrower (exsag.) depressed anterior band, which dies out well before margin; pleural and interpleural furrows subequal. Third and fourth posterior bands successively narrower; third anterior band indistinct, fourth absent. First posterior band confluent with first axial ring, proximally directed at 60° to the sagittal line, curving abaxially in a broad arc through about 180° before turning very slightly adaxially, ending opposite apex of axis. Posterior rib parallel to axial furrow, intervening ribs gradational between first and fourth. Posterior bands apparently extend as short spines, ending *en échelon*. Ends of third and fourth pleurae partially fused. Posterior bands of pleurae tuberculate; pleural lobe otherwise smooth.

Discussion. The Raheen cranidia most closely resemble that of '*Cybele*' *mchenryi* Reed, 1899, the holotype of which has recently come to light and is figured here (Fig. 48). Reed (1899: 752) gave the locality for this specimen (whose collector is not known) as Newtown Head, thus suggesting the Raheen Formation as the type horizon. However, the specimen is preserved in a dark limestone, a lithology not encountered in the section south of the Raheen Stream. It seems likely, therefore, that it is from the Tramore Limestone. The Raheen material differs primarily in the posterior border remaining narrow and ridge-like over most of its length; that of Reed's specimen expands from a short distance away from the occipital ring. The extent to which this simply reflects variation in one species will be assessed when the trilobites of the Tramore Limestone are described.

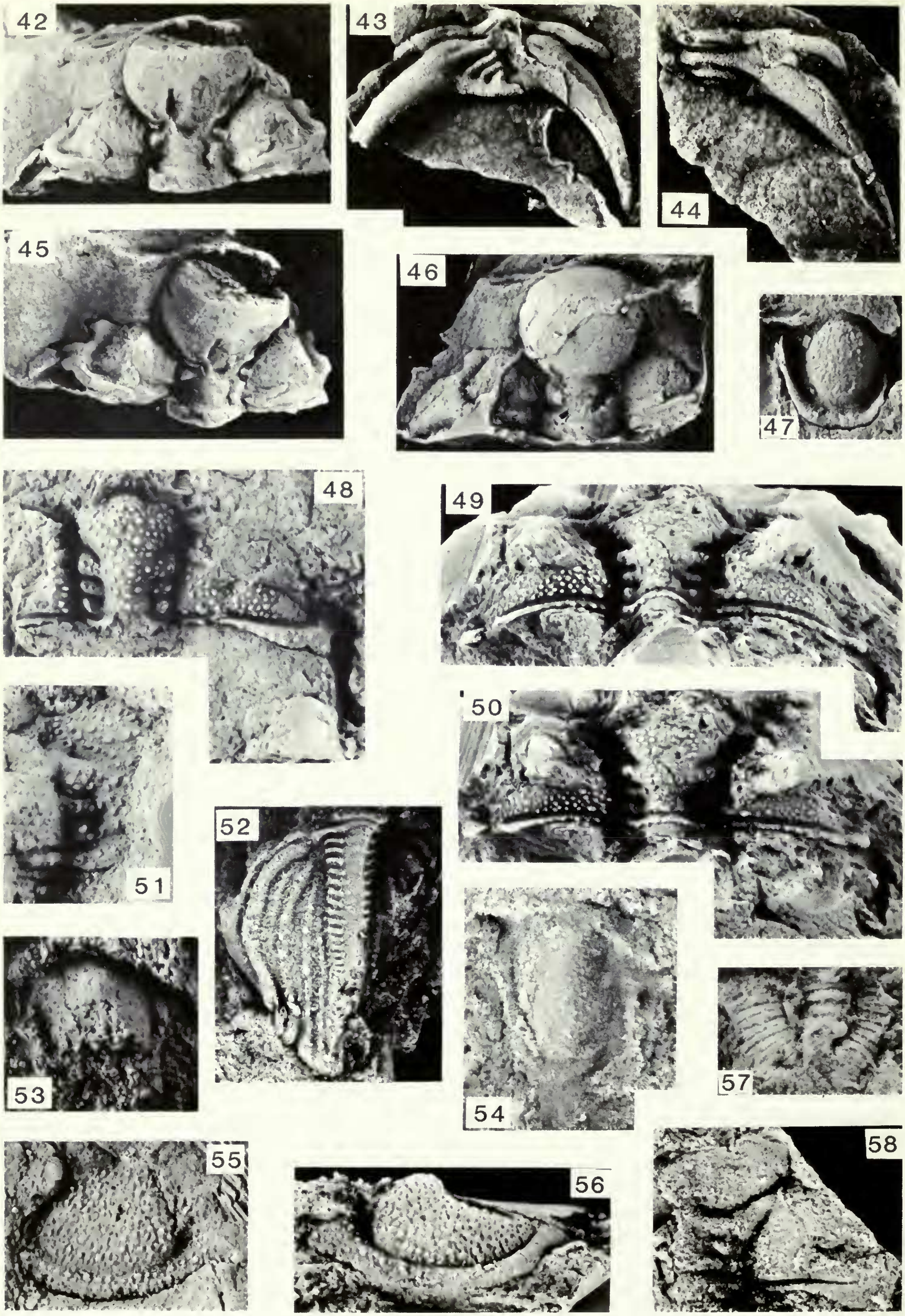
There is also a strong similarity to '*Deacybele*' *gracilis* (Nikolaisen, 1961) (see also Owen & Bruton 1980: 29; pl. 8, figs 14–17) from the highest Caradoc and basal Ashgill of the Oslo Region, Norway. The Raheen form differs in having longer S3 furrows, the posterior cranidial border only expanded distally and in having a shorter post-axial area on the pygidium. The anterior part of the cranidium is not known in the Raheen material but '*C.*' *mchenryi* has a median projection with three spines on it; '*D.*' *gracilis* has a single, robust tubercle.

Family **CALYMENIDAE** Milne Edwards, 1840

Subfamily **FLEXICALYMENINAE** Siveter, 1977

Genus ***FLEXICALYMENE*** Shirley, 1936

Type species. Original designation; *Calymene Blumenbachii* var. *Caractaci* Salter, 1865: 96; pl. 9, fig. 3. From the middle Caradoc of South Shropshire, England.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DISCUSSION. The status of *Reacalymene* Shirley, 1936 (type species *Reacalymene limba* Shirley, 1936) has been the subject of some debate (see Siveter 1977: 375), with most modern workers regarding it as a subgenus of *Flexicalymene*. Whittington (1965: 58) advocated that the name be restricted to the type species, and while Siveter (1977: 375) placed other species in the subgenus, he noted that it was 'most unlikely' that *F.* (*Reacalymene*) represented 'an evolutionary lineage separate from the nominate subgenus'. Siveter argued that there was a more distinct break in slope defining the posterior edge of the anterior border of the cranidium in species of *F.* (*Reacalymene*) than in other *Flexicalymene* species. The great intraspecific variability of the preglabellar area has been noted by several authors (e.g. Whittington 1965, Temple 1975, Siveter 1977) and Ingham (1977: 91) recorded an extreme variant of *Flexicalymene onniensis* Shirley *lata* Ingham with a frontal morphology like that of '*Reacalymene*'. In view of this, although the Raheen material described below has a frontal morphology approaching that of *F. limba*, the term '*Reacalymene*' is not used even at subgeneric level.

Flexicalymene sp.?nov.
Figs 59–70

?1899 *Calymene duplicata* Murch.; Reed: 723.

MATERIAL. This is the third most abundant species in the Raheen Formation, comprising 29 specimens (4·0% of the sample), which include all parts except the hypostoma.

DESCRIPTION. Cranidium slightly more than twice as wide as long. Blunt-ended glabella subparabolic in outline, occupying 80–85% of sagittal length of cranidium. Glabella tapers gently and evenly forwards, such that its width at L3 is about 80–85% of that at L1. Occipital ring occupies 15% of sagittal glabellar length, tapering to about half its mesial width behind L1. Occipital furrow transversely directed mesially, where it is shallow on the external surface but deep on internal moulds; it deepens behind L1 where it curves gently abaxially rearwards then slightly forwards to the axial furrow. L1 longer (exsag.) than wide (tr.); suboval to angular in outline, occupying about 55–60% of the glabellar width and defined adaxially by a shallow longitudinal furrow from S1 to the occipital furrow. S1 directed adaxially rearwards at about 65–70° to the sagittal line from the dorsal furrow, turning rearwards through about 120° behind the anteromesial part of L1; a short extension of this proximal portion of S1 extends behind the posteromesial part of L2. A shallow longitudinal furrow connects this part of S1 with S2, and thus L2 is completely circumscribed by furrows and is approximately circular in outline. S2 transversely directed distally, bifurcating adaxially to define the anteromesial part of L2 and posteromesial part of L3. S3 short (tr.), transversely directed, barely discernable on

Figs 42–47 *Sphaerocoryphe murphyi* sp. nov. Figs 42, 45, 46, It.17461a, b, dorsal and oblique dorsal views of internal mould of cranidium, dorsal view of latex cast of external mould, all × 2. Fig. 43, It.19452, dorsal view of latex cast of distorted pygidium, × 2½. Fig. 44, **holotype,** BM(NH) It.19453, dorsal view of latex cast of incomplete pygidium, × 2. Fig. 42, It.17460a, ventral view of internal mould of hypostoma, × 3. Raheen Formation, sample 3. See p. 107.

Fig. 48 '*Cybele*' *mchenryi* Reed. Holotype, GSI:F01311, dorsal view of internal mould of cranidium, × 4. Original of Reed (1899: fig. 7). Probably Tramore Limestone Formation, Co. Waterford. See p. 109.

Figs 49–56 Cybelinae indet., cf. '*Cybele*' *mchenryi* Reed. Figs 49, 50, It.19454, oblique dorsal and true dorsal views of internal mould of cranidium, both × 4, sample 3. Fig. 51, It.19455, dorsal view of latex cast of incomplete cranidium, × 6, sample N. Fig. 52, It.17480, dorsal view of internal mould of pygidium, × 6, sample 3. Fig. 53, It.19456, ventral view of internal mould of incomplete hypostoma, × 7, sample 3. Fig. 54, It.17477, ventral view of internal mould of distorted hypostoma, × 6, sample 3. Fig. 55, It.17456, lateral view of internal mould of incomplete free cheek, × 6, sample 3. Fig. 56, It.19457, lateral view of free cheek lacking eye, × 4, sample 3. Raheen Formation. See p. 108.

Figs 57–58 *Calyptaulax* sp. Fig. 57, It.17472, dorsal view of incomplete cranidium, × 6. Fig. 58, It.17471, dorsal view of incomplete internal mould of cranidium, × 4½. Raheen Formation, sample 3. See p. 114.

external surface, more deeply impressed on internal moulds where the small, circular L3 is more clearly developed. Some internal moulds show a very weakly developed L4. Glabella narrows only very slightly in front of L3. Axial furrows deep, converging forward at 20–25°. Preglabellar area comprising a preglabellar furrow and a ridge-like anterior border; there is commonly, but not invariably, a distinct change in slope between the two. Anterior border maintains its width except at its distal extremities, where it tapers. In profile the border varies from curved to more flat-topped. Posterior border expands (exsag.) abaxially, defined anteriorly by a border furrow which is narrow and deep proximally, becoming broader and much shallower abaxially. Mid-length points of palpebral lobes situated opposite L2 but the distortion of many specimens makes this difficult to assess. Anteriorly the fixed cheek field extends to opposite or slightly in front of the end of the glabella. Posterior branch of facial suture directed transversely or even forwards slightly over most of the genal field; curving gently rearwards laterally it cuts the lateral border a short distance in front of the genal angle. Anterior branch virtually parallel to sagittal line over most of its length, curving adaxially forwards across the anterior border. Free cheek almost quadrant-shaped. Border and broad shallow border furrow maintain their width over the entire outer arc of the cheek. Eye socle defined abaxially by a broad, very shallow depression. External, and to a lesser extent internal, surface of cephalon densely covered by fine granules. Hypostoma not known.

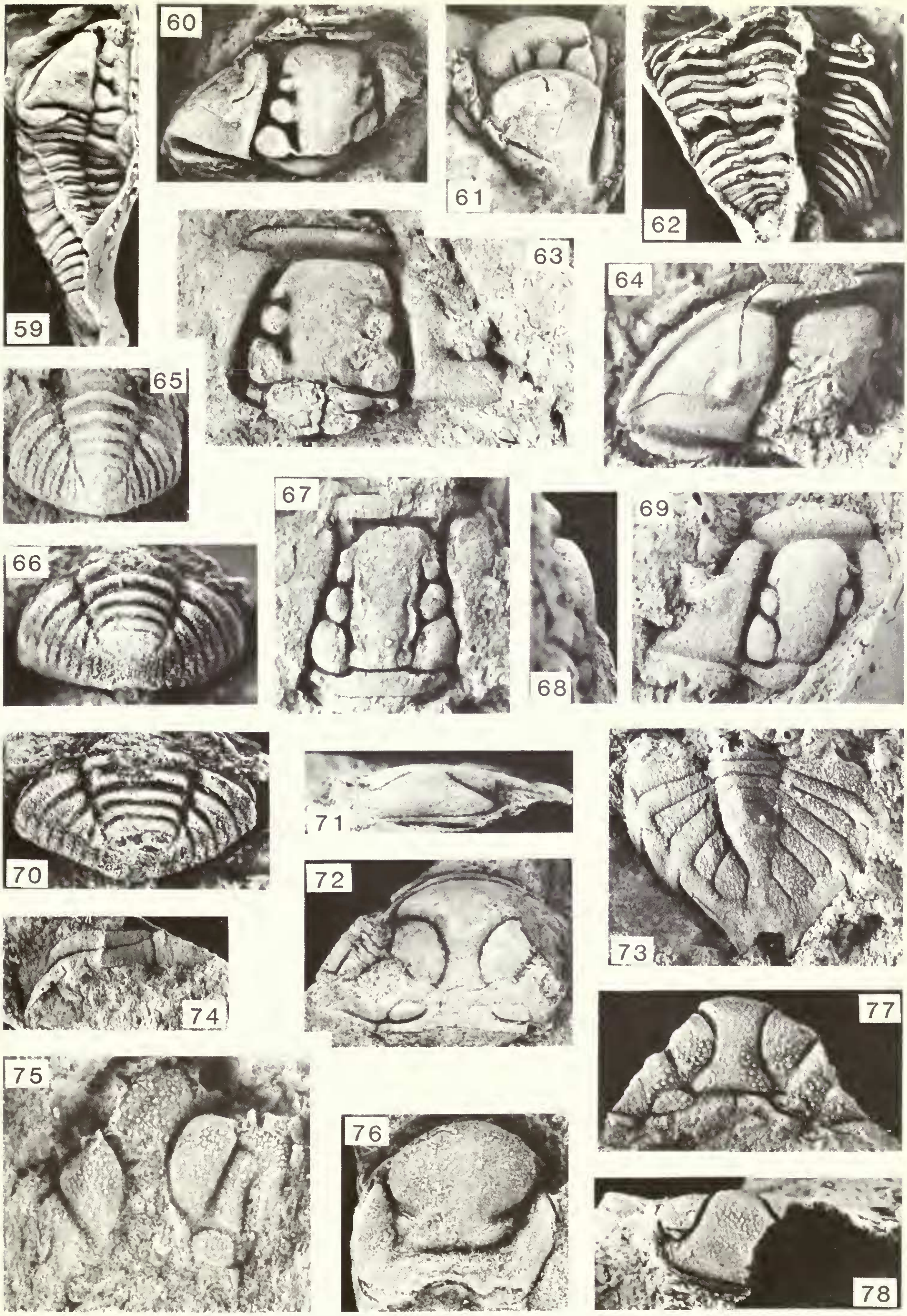
Thorax of 13 segments. Axis strongly convex (tr.); articulating half-rings equal in length (sag.) to about 50% of that of the rings. Axial furrows narrow (tr.) and shallow, but mark a distinct change in slope. Pleurae with deep furrows defining a broad (exsag.) posterior band and a narrower anterior band. The latter expands at the fulcrum to form an articulating boss. Abaxially from the fulcrum each segment is deflected steeply downwards and gently rearwards, curving gently forwards distally. External surface of thorax, excluding furrows, bears a fine, dense granulation.

Pygidium strongly convex (tr., sag.). Maximum width of axis half that of pygidium. Axis moderately convex, tapering rearwards at about 30–40°; it is blunt-ended and comprises six rings and a short terminal piece. Ring furrows deep, arched very gently forwards. Axial furrows deep except posteriorly. Anteromesial parts of pleural lobes gently declined; anterolateral and posterior parts steeply so. Four ribs and a broad (tr.) post-axial area present. Pleural furrows broad and distinct; interpleural furrows narrow, becoming shallower and in some instances dying out adaxially. External surface, and internal mould, of pygidium excluding furrows densely covered by fine granules.

Discussion. The well-differentiated anterior border in most of the Raheen cranidia suggests an affinity with species previously placed in '*Reacalymene*', the type species of which, *R. limba* Shirley from the Soudleyan of north Wales, was redescribed by Whittington (1965: 58–59; pl. 16,

Figs 59–70 *Flexicalymene* sp. ?nov. Fig. 59, It.19458, dorsal view of latex cast of incomplete articulated individual, × 2, sample 3. Figs 60, 61, It.17488, dorsal and lateral views of incomplete distorted cranidium, both × 3, sample 3. Fig. 62, It.19712, dorsal view of latex cast of incomplete thorax and pygidium, × 3½, sample 5. Fig. 63, It.17732, dorsal view of internal mould of incomplete cranidium, × 4, sample 3. Fig. 64, It.19459, dorsal view of internal mould of incomplete cephalon, × 3½, sample 3. Fig. 65, It.19460, dorsal view of internal mould of narrow pygidium, × 7½, sample 3. Figs 66, 70, It.19461, dorsal view, × 6, and view normal to axial terminal piece, × 6½, of broad pygidium, sample 3. Fig. 67, It.17464, dorsal view of internal mould of incomplete flattened cranidium, × 3½, sample 3. Figs 68, 69, It.19462, lateral and dorsal views of latex cast of incomplete cranidium, both × 5½, sample 3. Raheen Formation. See p. 111.

Figs 71–78 *Platylichas laxatus* (M'Coy). Figs 71, 72, It.17468, frontal and dorsal views of internal mould of incomplete cranidium, both × 2. Fig. 73, It.19463, dorsal view of latex cast of pygidium, × 4. Fig. 74, It.17453, dorsal view of latex cast of incomplete thoracic segment, × 3½. Fig. 75, It.17473, dorsal view of internal mould of incomplete cranidium, × 6. Fig. 76, It.17482, ventral view of internal mould of hypostoma, × 4½. Figs 77, 78, It.19464, dorsal and frontal views of internal mould of distorted incomplete cranidium, both × 6. Raheen Formation, sample 3. See p. 115.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figs 9–20). As in the Raheen sample, the Welsh species shows a range of cranidial morphology, but the Irish form differs consistently in having a more blunt-ended glabella which tapers less strongly. *F. limba* also commonly has a more evenly tapered anterior border, although one specimen illustrated by Whittington (1965: pl. 16, fig. 10) approaches the condition seen in the Irish cranidia. The shape of L1 in some of the Irish cranidia approaches the angularity considered by Whittington to be characteristic of *F. limba*, but others are much more oval in outline. None of the Welsh cranidia have L4 present. Whittington regarded the absence of interpleural furrows on *F. limba* pygidia as a feature distinguishing it from *F. pusulosa* (see below), but they are clearly visible on one of the specimens he illustrated (pl. 16, figs 19, 20).

Like the Raheen form, a blunt-ended glabella and a weakly developed L4 are also seen in *F. pusulosa* (Shirley), from the Costonian of south Shropshire, which was placed in *Reacalymene* by Shirley (1936). The holotype was reillustrated by Dean (1963: pl. 37, figs 9, 11). *F.* sp. ?nov. differs from the Shropshire species in having the glabella markedly broader at L4 than at L3, and the anterior border is less tapered and not as flat. A pygidium illustrated by Dean (1963: pl. 37, fig. 12) also has seven axial rings, as against six in the Irish specimens. Siveter (1977: 375–377, figs 10A–D) described a cranidium from the Oslo region as being close to *F. pusulosa*. Most of the features cited by Siveter as distinguishing it from *F. pusulosa* also differentiate it from the Raheen material. As Siveter suggested, the horizon of the Norwegian specimen is somewhat problematical. The cranidium is from Ballangrud in Hadeland, but the stated horizon, the late Caradoc 'Upper Chasmops Limestone' (= Solvang Formation) does not crop out there. Other museum specimens similarly labelled are of species clearly from the Ashgill Kjørrven Formation or Grina Shale Member of the Lunner Formation (see Owen 1978 for stratigraphy) which accord with recent mapping in the area.

Indeterminate material of *Flexicalymene* described by Siveter (1977: 355–356, figs 10I, K) from the 'Lower Chasmops Shale' (low Caradoc) of the Oslo region includes a cranidium with a glabellar shape and preglabellar area similar to that of *F.* sp. ?nov. It differs, however, in having a coarser external granulation; L1 and L2 are less well circumscribed by furrows and S3 more deeply impressed.

F. planimarginata Reed, 1906 (see also Whittington 1965: 60–61; pl. 17, figs 8–13, 16, 17, 20–22) from Longvillian strata in Wales and the Welsh Borderland has a blunt-ended glabella like that of *F.* sp. ?nov., but the glabella of the latter is less tapered and the preglabellar area shorter (sag., exsag.).

Family **PTERYGOMETOPIDAE** Reed, 1905

Subfamily **PTERYGOMETOPINAE** Reed, 1905

Genus ***CALYPTAULAX*** Cooper, 1930

TYPE SPECIES. Original designation; *Calyptaulax glabella* Cooper, 1930: 388–389; pl. 5, figs 9–11. From the Matapédia Group (Ashgill), Percé, Quebec, Canada.

Calyptaulax sp.
Figs 57–58

MATERIAL. Three cranidia, a thoracic segment and two pygidia, all poorly preserved, comprising 0·8% of the Raheen trilobite fauna.

DISCUSSION. Whilst the cranidia placed here undoubtedly belong in *Calyptaulax*, the more complete of the two pygidia is unusual in showing the rib furrows (= interpleural furrows) extending to the axial furrows—a feature more characteristic of other pterygometopids such as *Achatella* Delo, 1935 (see Ludvigsen & Chatterton 1982) and members of the Chasmopinae (see McNamara 1980, 1980a).

The strongly geniculate S3 may partially reflect compactional deformation, but it resembles the condition in *C.* aff. *norvegicus* Størmer of Whittington (1962: pl. 2, figs 17, 18) and *C. planiformis* Dean, 1962 (see also Owen & Bruton 1980: 34) from the Ashgill of Wales and northern England. Both may prove to belong in *C. norvegicus* (see Owen 1981: 63–64) which in turn is close to the type species, *C. glabella* (see Ludvigsen & Chatterton 1982: 2192–2194).

Family **LICHIDAE** Hawle & Corda, 1847

Subfamily **HOMOLICHINAE** Phleger, 1936

Genus ***PLATYLICHAS*** Gürich, 1901

TYPE SPECIES. Original designation; *Lichas margaritifer* Nieszkowski, 1857: 568; pl. 1, fig. 15. From the Porkuni Limestone (upper Ashgill) of Estonia.

Platylichas laxatus (M'Coy, 1846)
Figs 71–78

1846 *Lichas laxatus* M'Coy: 51; pl. 4, fig. 9.
1854 *Lichas sexspinus* Angelin: 74; pl. 38, figs 7–8a.
1854 *Lichas aculeatus* Angelin: 75; pl. 38, figs 7, 7a.
1899 *Lichas laxatus* M'Coy; Reed: 723.
1958 *Platylichas laxatus* (M'Coy) Tripp: 579; pl. 85, figs 3, 4 (*non* fig. 5, = *P. nodulosus* M'Coy)
1963 *Platylichas laxatus* (M'Coy); Dean: 235–237; pl. 43, figs 1, 2, 5, 8–12.
1979 *Platylichas laxatus* (M'Coy); Hurst: 204, fig. 16.5.
1979a *Platylichas laxatus* (M'Coy); Hurst: 210, fig. 41.
1980 *Platylichas laxatus* (M'Coy); Owen & Bruton: 34–35; pl. 10.

For more complete synonymy lists of this species see Dean (1963) and Owen & Bruton (1980).

MATERIAL. Cranidia, hypostomata, a thoracic segment and pygidia of this species constitute 1·3% of the Raheen fauna.

DISCUSSION. Cranidia from the Raheen Formation agree closely with those of *P. laxatus* from the type locality, Ballygarvan Bridge (see Tripp 1958: pl. 85, figs 3, 4). The length/width ratio shows considerable variation at both localities and there are no consistent differences. Other parts have not been described from Ballygarvan Bridge but are present in the Tripp collection at the BM(NH). Those from Raheen and specimens associated with *P. laxatus* cranidia elsewhere (see e.g. Dean 1963, Owen & Bruton 1980) are identical to the Ballygarvan Bridge material.

P. laxatus is an extremely common and variable species in upper Caradoc units in the British Isles and Scandinavia. The variability affects particularly the degree of inflation of the bullar lobes (see Temple 1972) in relation to the central lobe and the width and outline of the anterior border. This cranidial variability may even encompass or at least overlap with the morphologies of *P. nodulosus* (M'Coy, 1851), *P. glenos* Whittington, 1962 and *P. noctua* Price, 1980, but further study is required to establish whether these forms should be reassigned to *P. laxatus*. *P. thraivensis* (Reed, 1935: see Tripp 1958: 579) from the Rawtheyan Starfish Beds of Girvan is allied to *P. laxatus* but differs in its more posteriorly placed palpebral lobes.

Family **ODONTOPLEURIDAE** Burmeister, 1843

Subfamily **ODONTOPLEURINAE** Burmeister, 1843

Genus ***PRIMASPIS*** Richter & Richter, 1917

TYPE SPECIES. Original designation; *Odontopleura primordialis* Barrande, 1846: 29. From the Letná Formation (Caradoc) in Bohemia. (See Chatterton & Perry 1983: 33 and Ramsköld 1984: 241 for discussions of the genus.)

Primaspis aff. ***caractaci*** (Salter, 1853)
Figs 79–84

MATERIAL. Cranidia, free cheeks and pygidia constitute 2·8% of the Raheen trilobite fauna.

DISCUSSION. *Primaspis caractaci* (Salter) from the Marshbrookian and Actonian of south Shropshire was redescribed by Dean (1963: 239–241; pl. 44, figs 3, 7, 9, 11, 13, 14). The overall cranidial proportions of the Raheen material are very similar to those of Salter's species except that the glabella is proportionally broader and less tapered in front of L2. The pygidium may differ slightly in having three rather than two spines outside the large major spines, but the third (anteriormost) spine is very small in the Raheen form, and thus may simply not be preserved in the Shropshire specimens. As Dean noted (1963: 240–241) the cranidium of *P. caractaci* is broadly comparable with that of the Harnagian *P. harnagensis* (Bancroft, 1949) also from Shropshire, but the latter species may be distinguished primarily by the presence of four outer and two inner pairs of pygidial spines in addition to the primary spines. *P. caractaci* and the Raheen form both have three pairs of inner spines, the outer of which is not fused with the primary spines. This contrasts with the condition in *P. evoluta evoluta* (Törnquist) from the Ashgill of Sweden, north Wales and possibly Norway (see Owen 1981: 69) where the anteriormost of the three is fused with the base of the primary spines.

P. semievoluta (Reed, 1910) from the Longvillian of the north of England (see Dean 1962: 122; pl. 17, figs 3, 10, 11, 13, 15) has a very strongly tapering occipital ring and only two pairs of spines between the primary spines of the pygidium. These differences also apply to *P. llandowrorensis* Price, 1980 from the Ashgill of Wales, which also has the field of the fixed cheek a little broader than in the present *P.* aff. *caractaci*. *P. bucculenta* McNamara, 1979 from the Ashgill of northern England and Norway (see Owen 1981: 70) has a much broader fixed cheek field than any of these species, and whilst there are three pairs of spines between the primary spines of the pygidium there is only one or possibly two pairs outside them.

Subfamily **MIRASPIDINAE** Richter & Richter, 1917

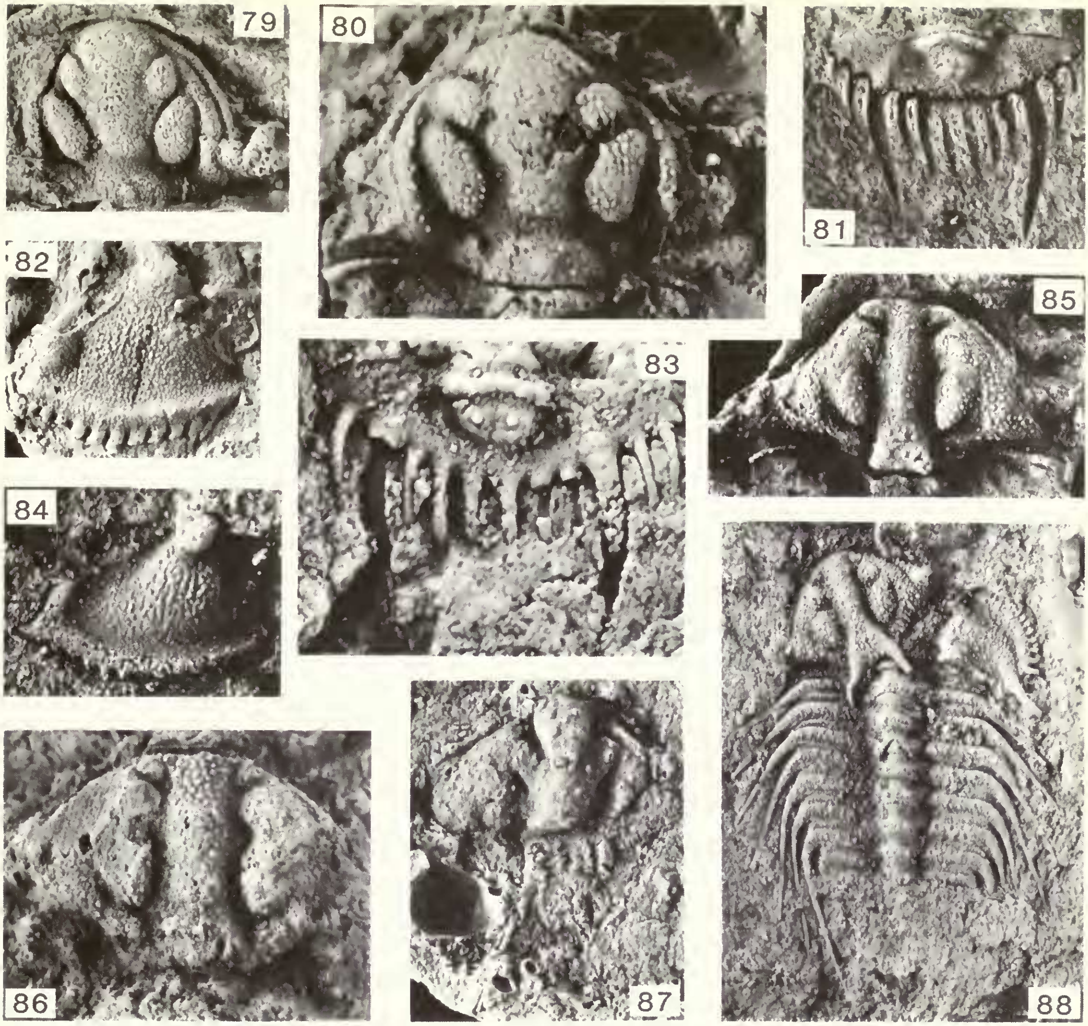
Genus ***MIRASPIS*** Richter & Richter, 1917

TYPE SPECIES. Original designation; *Odontopleura mira* Barrande, 1846: 57. From the Liteň Formation (Wenlock) near Beroun, Czechoslovakia.

Miraspis sp.
Figs 85–88

MATERIAL. Four cranidia and a slightly disarranged moult lacking the pygidium comprise 0·7% of the Raheen trilobite fauna.

DESCRIPTION. Length of cranidium (excluding occipital spines) slightly greater than half posterior width. Occipital ring narrow and long, occupying 25–30% of the sagittal glabellar length, tapering gently forwards and marked anteriorly by a very shallow furrow or even just a slight break in slope—the ring being more flat-lying than the preoccipital part of the glabella. No median occipital spine/tubercle is present, but a pair of long spines diverges rearwards and slightly upwards from the posterior edge of the occipital ring at about 60°. Preoccipital part of glabella almost circular in outline. Median lobe of glabella parallel-sided, defined by deep furrows as far forward as L3, and occupying 30% of the maximum width of the glabella, at the anterior ends of L1. L1 longitudinally oval, expanding (tr.) forwards over nearly three-quarters of their length. S1 diverge forwards at about 120°, dying out abaxially such that an extension of L1 is confluent with the subcircular L2. S2 diverge forwards at about 140°, broad and deep proximally, narrowing and becoming shallower abaxially. L3 undifferentiated anteriorly from the short (sag., exsag.) frontal lobe. Axial furrows well incised behind and along the posterior half of L1, where they curve abaxially forward from being transversely directed to being parallel. In front of this the glabella is differentiated from the fixed cheeks only by a break in slope. Field of fixed cheek almost triangular in outline, generally tapering forward but with a broad (exsag.) area extending behind L1 to the occipital ring. Posterior part of field steeply inclined from the posterior border. Posterior border ridge-like, directed gently abaxially in which direction it broadens a little, defined anteriorly by a deep, transversely-directed furrow. Base of eye stalk situated opposite the mid or anterior parts of L1. Details of stalk not known. Eye ridge defined adaxially by a shallow furrow directed from the base of the eye stalk to the anterolateral corner of the glabella at an angle to the sagittal line of about 40°. Anterior branch of facial suture defines the abaxial edge of this ridge. Details of posterior branch not known. External surface and internal mould of cranidium, excluding furrows, bear a dense coarse granulation.



Figs 79–84 *Primaspis* aff. *caractaci* (Salter). Fig. 79, It.19465, dorsal view of latex cast of cranidium, × 6½, sample N. Fig. 80, It.19466, dorsal view of internal mould of cranidium, × 11, sample 3. Fig. 81, It.17479, dorsal view of internal mould of pygidium, × 7, sample 3. Fig. 82, It.19467, oblique lateral view of latex cast of free cheek, × 6, sample 3. Fig. 83, It.17751, dorsal view of internal mould of pygidium, × 13, sample 3. Fig. 84, It.19468, oblique lateral view of internal mould of free cheek, × 6, sample N. Raheen Formation. See p. 115.

Figs 85–88 *Miraspis* sp. Fig. 85, It.17450, dorsal view of internal mould of cranidium, × 4, sample 3. Fig. 86, It.19469, dorsal view of internal mould of incomplete cranidium, × 8, sample 3. Fig. 87, It.19470, dorsal view of latex cast of incomplete cranidium showing long occipital spine, × 6, sample N. Fig. 88, It.17448, dorsal view of latex cast of slightly disarranged moult, lacking pygidium, × 4, sample 3. Raheen Formation. See p. 116.

Free cheek triangular in outline. Inner part of field steeply declined from the eye stalk but flattening out and becoming concave laterally and anteriorly adjacent to the weakly swollen border. Border bears at least 16 short, evenly-spaced spines. The main librigenal spine, of unknown length, is situated some distance behind the smaller spines and is an extension of a distinct swelling on the posterior part of the field. The adaxial part of the spine-base is abutted by a narrow posterior sutural ridge. External surface of free cheek densely covered by coarse granules.

Hypostoma not known.

Thorax of at least eight segments, tapering gently rearwards, known from a single specimen which lacks a pygidium. Axis strongly convex (tr.), occupying a quarter or less of the width of each segment. Axial furrow no more than a break in slope. Pleurae flat-lying, transversely directed. Principal pleural ridge (see Bruton 1966: 3–4 for definition of this and related terms) strongly swollen (exsag.) on anterior segments, progressively a little less so posteriorly; transversely directed except at distal extremity where it turns sharply rearwards. Long slender principal pleural spine directed abaxially rearwards at 60° to the sagittal line on the first segment and adaxially rearwards at 20° on the 7th (details of 8th not known). The orientation of the spines on the intervening segments form a gradation between these directions. Anterior accessory area bearing a well-developed ridge on the anterior segments; this is much less prominent posteriorly along the thorax. Posterior accessory area narrow (exsag.), poorly differentiated from the principal pleural ridge. An anterior pleural spine is visible on the first segment but this part of the segment is not preserved in the rest of the thorax. External surface of axis and pleural ridges densely covered in coarse granules. Posterior accessory areas and proximal parts of spines are more finely granular. Granulation on internal mould much more subdued.

Pygidium not known.

Discussion. The present material is described under open nomenclature pending the revision of *Miraspis jamesii* (Salter, 1853) from the Tramore Limestone. Salter's species was based on an articulated thorax and pygidium originally included in *Whittingtonia bispinosa* (M'Coy 1846), the lectotype of which is a cephalon from the Chair of Kildare Limestone (Ashgill) of Co. Kildare (see Warburg 1925: 251; Bruton 1966: 27; Dean 1974: 94).

The absence of a median occipital protruberance and the weakly incised occipital furrow distinguish the Raheen form from *M. ceryx* Whittington & Bohlin, 1958, *M. solbergensis* Bruton, 1966 and *M. cornuta* (Beyrich, 1846) from the Ordovician of Sweden, and suggest an affinity to *M.* sp. of Owen & Romano (*in* Harper *et al.* 1984). This last form is from the upper Ordovician Clashford House Formation and although incompletely known, its cranidium appears to differ in having a broader (tr.) median glabellar lobe and a more circular L1.

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